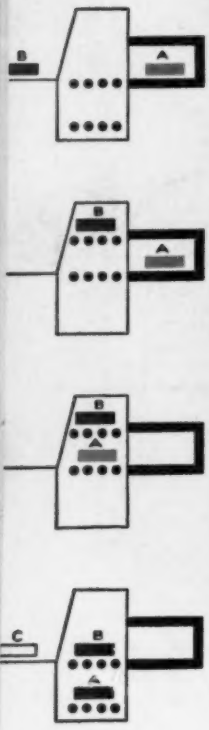
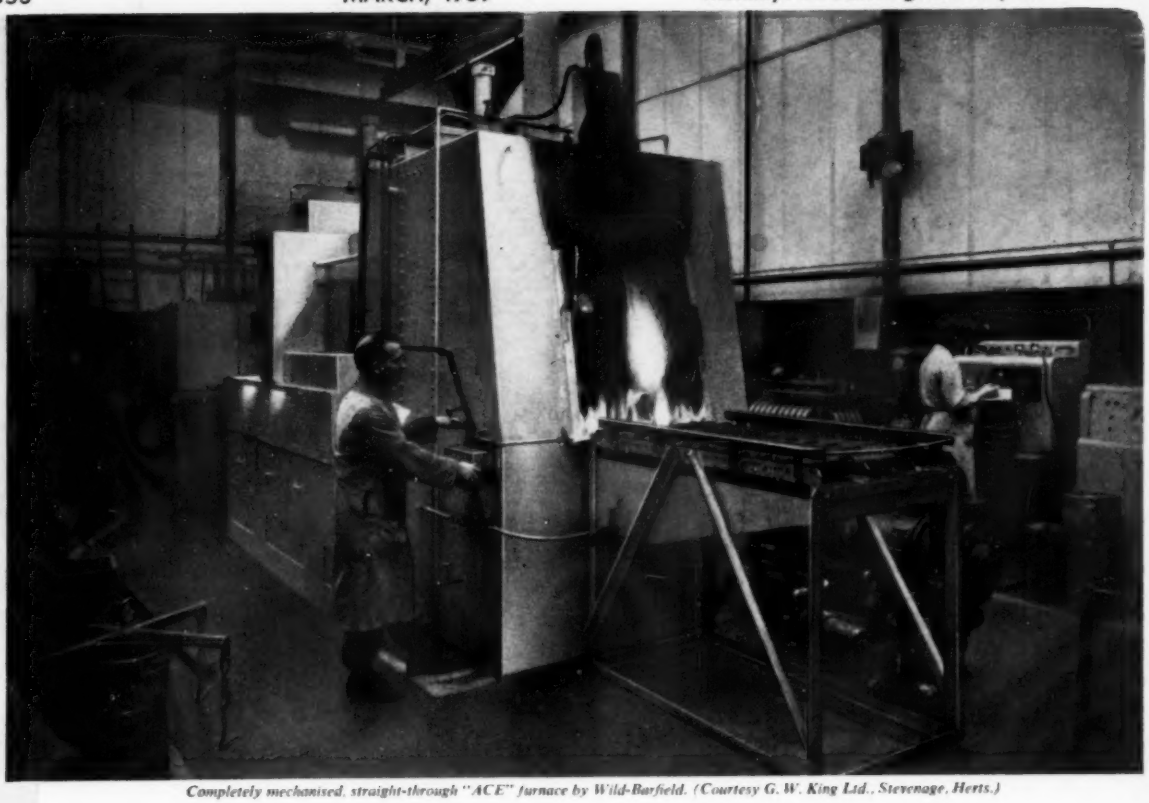
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 59 No. 353 MARCH, 1959 Monthly: Two Shillings and Sixpence





Completely mechanised, straight-through "ACE" furnace by Wild-Barfield. (Courtesy G. W. King Ltd., Stevenage, Herts.)

WILD BARFIELD

'ACE' sealed quench furnaces

- VERSATILE IN APPLICATION
  Carbonitriding, Clean Gas Carburising, Clean Hardening and Normalising
- TROUBLE-FREE OPERATION
  Electric radiant tube elements
- CENTRAL CONTROL CUBICLE
  All doors and quench lift hydraulically operated
- RANGE OF SIZES
  Covers all normal requirements

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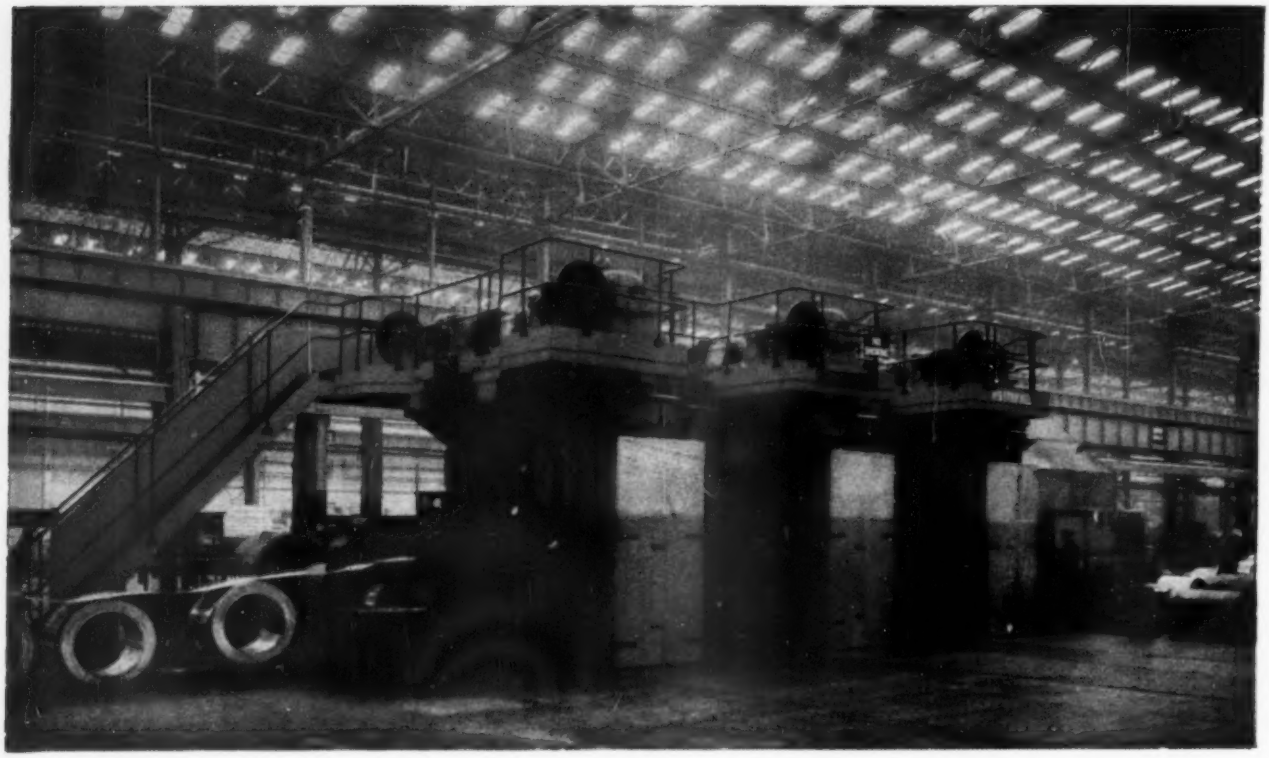

ROLLING MILLS

for the

NON-FERROUS INDUSTRY

The illustration shows the 15" and 38" x 44" 3-Stand Tandem Mill in operation in the Falkirk Works of the British Aluminium Company Limited. This Mill produces strip up to 38" wide in finished gauges normally ranging from 0.012" up to 0.022".

Builders of capital equipment for the metal industries

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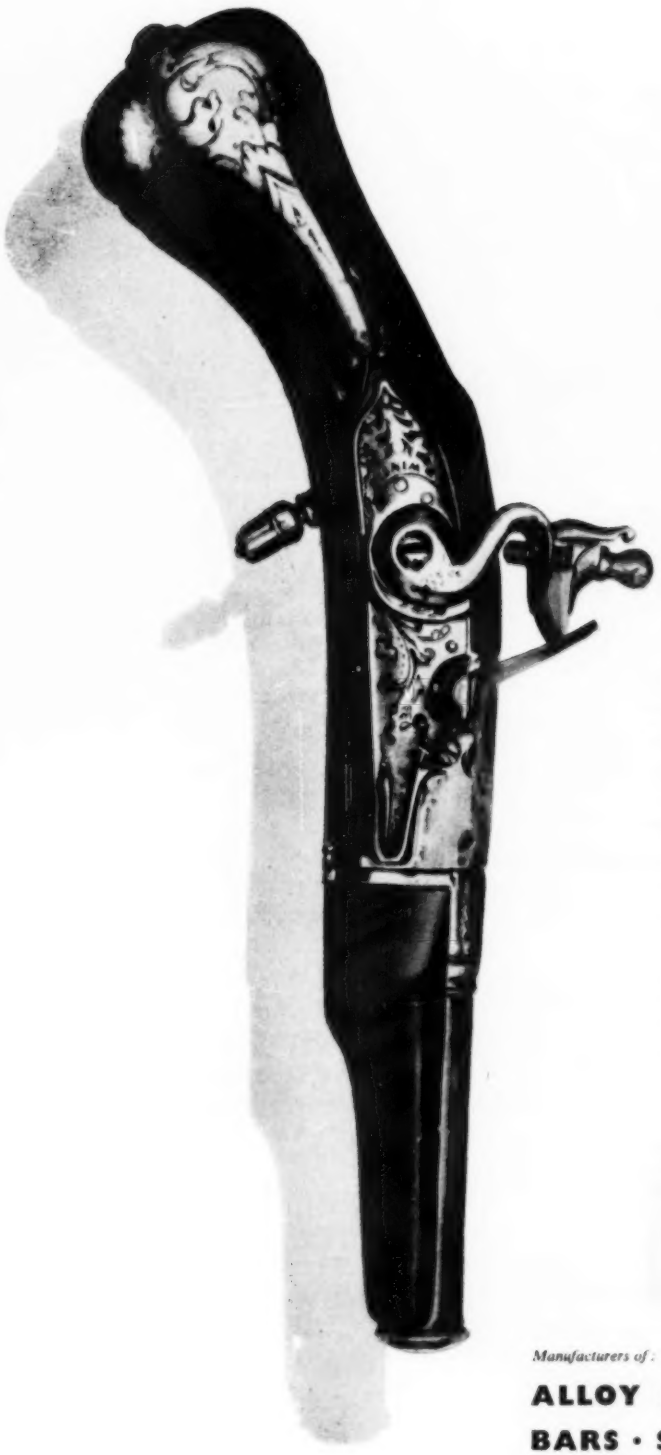

Characteristic of British Craftsmanship is this handsomely worked pistol. Made in the 16th Century from steel and wood it is a fine example of the work of that period and can be seen in the Victoria and Albert Museum.

Britain is proud of her craftsmen; throughout the years their skilled workmanship has earned a reputation for Britain that is second to none. The historical associations of steel in England chronicled through the ages, show how dependent we have become upon its production. Today its manifold uses in industry and everyday life have become legion—civilisation itself is woven over a framework of iron and steel. Hallamshire high grade Alloy and Carbon steels are an integral part of Britain's traditional good name.

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Manufacturers of:

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WIDE STRIP MILLS
are served by
"RUST" Continuous Slab Reheating Furnaces
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by S & A

S & A STEIN & ATKINSON LTD. LONDON

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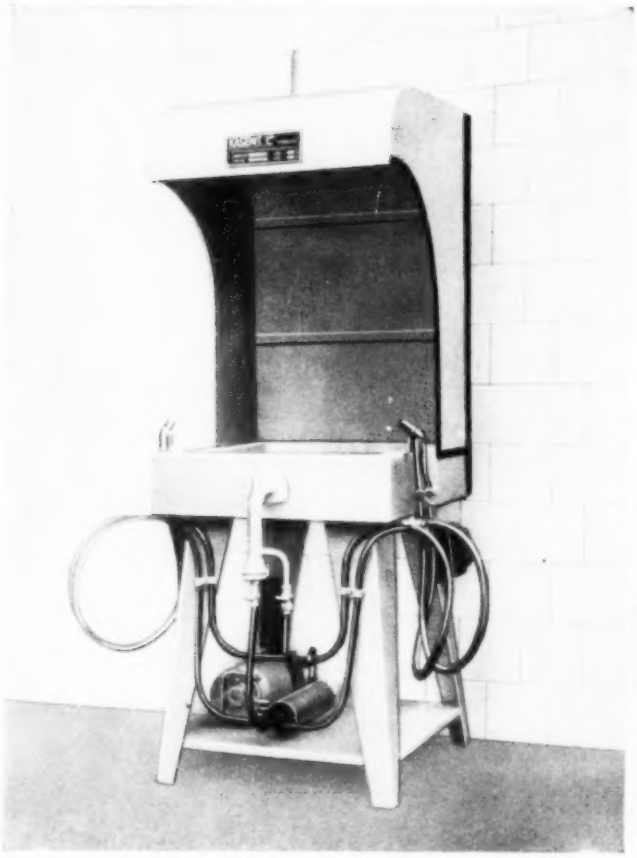


GAS BLAST COMBINED FORGE AND BRAZING HEARTH

Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.

NATURAL DRAUGHT GAS FIRED SALT BATH SUITABLE FOR CYANIDE OR NEUTRAL SALTS

Suitable for temperatures up to 900° C.

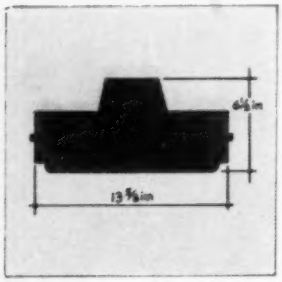
Obtainable in the following sizes :
8 in. dia. × 8 in. deep, gas consumption 300 cu. ft./hr.
8 in. dia. × 10 in. deep, gas consumption 350 cu. ft./hr.
10 in. dia. × 12 in. deep, gas consumption 400 cu. ft./hr.

Time to heat up—1½ hours.

Manufactured by

KASENIT LTD

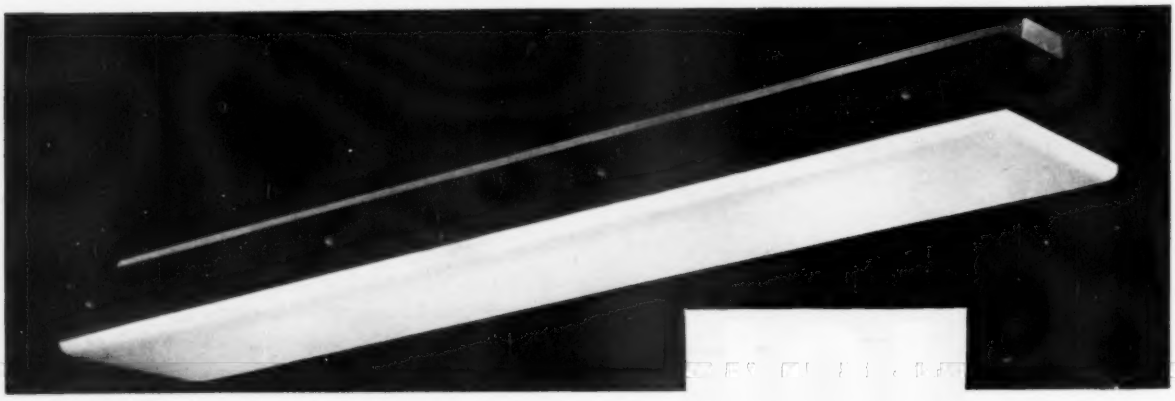
7, HOLYROOD STREET · BERMONDSEY · LONDON, S.E.1



one of many decorative designs

The brilliantly successful G.E.C. 101 range of fluorescent fittings offers a wide choice of designs for every lighting requirement — in executive offices, showrooms, shops and stores, as well as factory areas. They are made for 1½ to 8 ft. single or twin Osram guaranteed tubes, and all employ the famous G.E.C. Basic Channel with its proven advantages of versatility and economy in installation and maintenance.

The fitting illustrated, F41138/9, consists of a standard channel with special wide spacing lampholder assembly, together with a metal frame with applied mahogany finish supporting a 040 "Perspex" diffuser.



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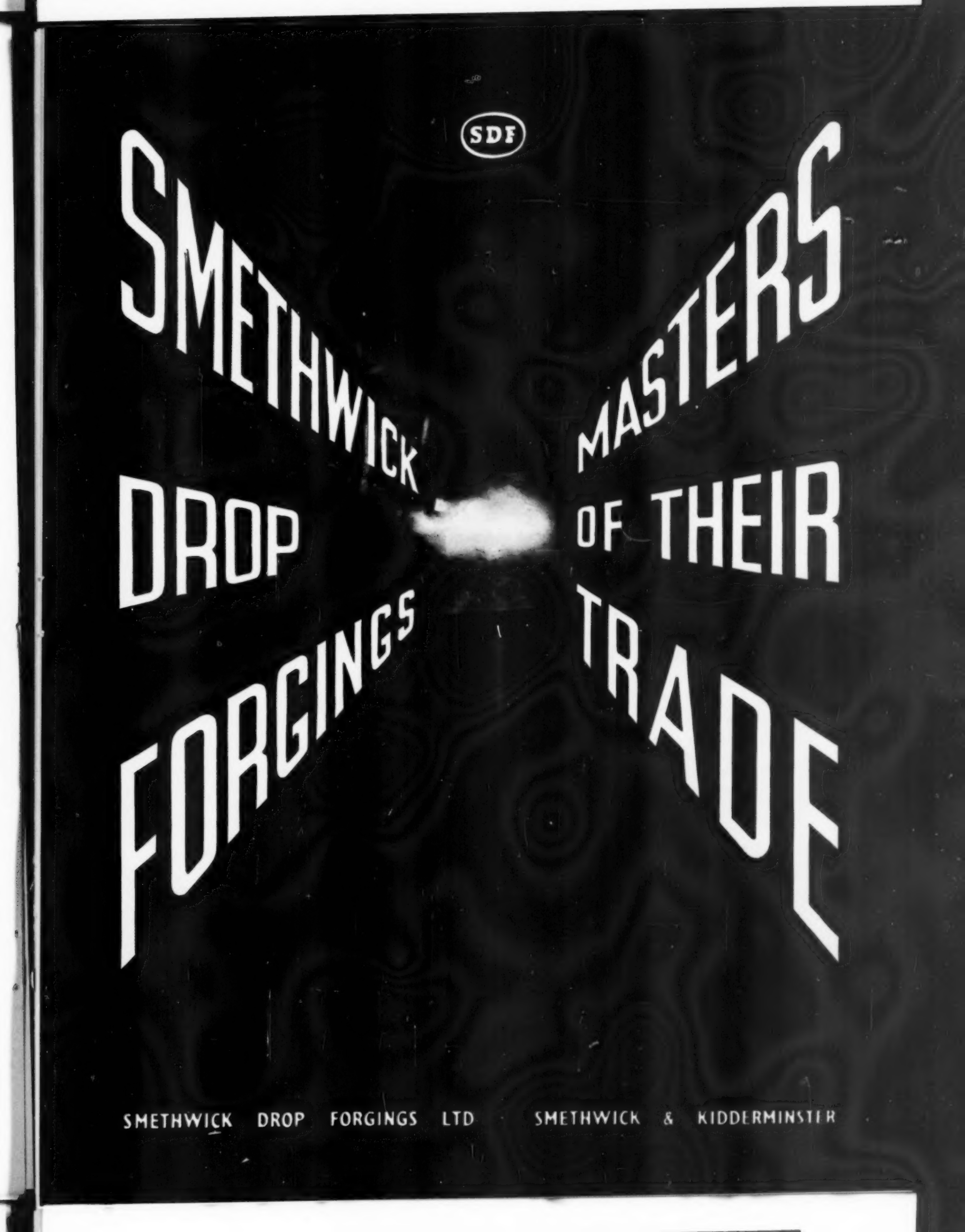
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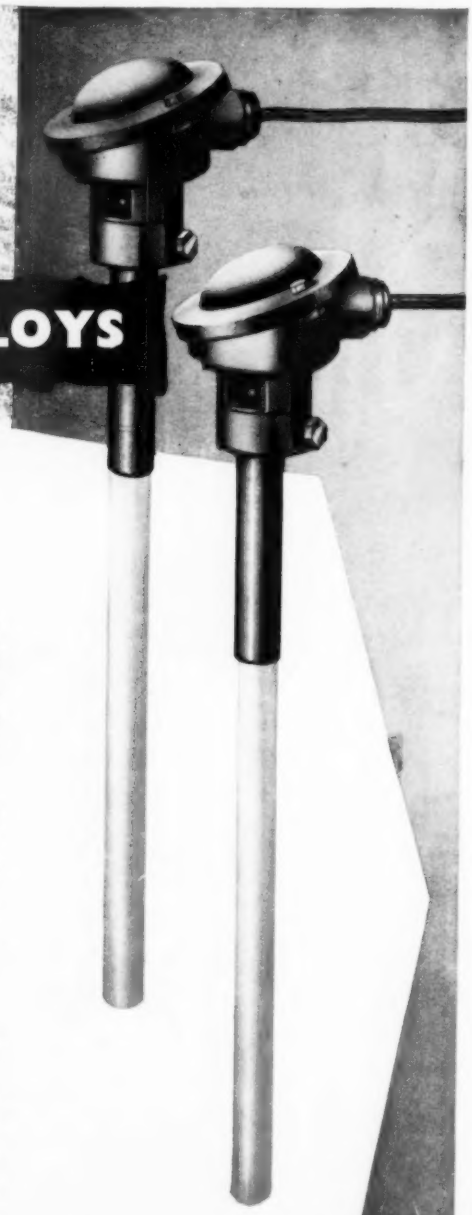

"Ni-Cr (plus) v/s Ni-Al (minus)"

Conforming to B.S. 1827:1952

The Thermo-electric properties of the Nickel-Chromium/ Nickel-Aluminium Alloys "Ni-Cr(Plus)" and "Ni-Al (Minus)", are in strict conformity with those stated in the American National Bureau of Standards Circular 561, and British Standard Institution Reference Tables for Thermocouples, B.S. 1827:1952.

For Compensating Cables and Extension Leads in Civil and Military Aircraft, "Ni-Cr(Plus)"/"Ni-Al(Minus)" Wires have Ministry of Supply (Air) type approval, for Cables manufactured to Specifications EL. 1705 and 1632.

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We manufacture a special quality of Thermocouple iron and are able to supply matched wires in the Iron v Constantan combination to meet customers' varied Thermal-EMF requirements. Furthermore, and of infinitely greater importance, we are able to guarantee the reproducibility of those thermo-electric properties.

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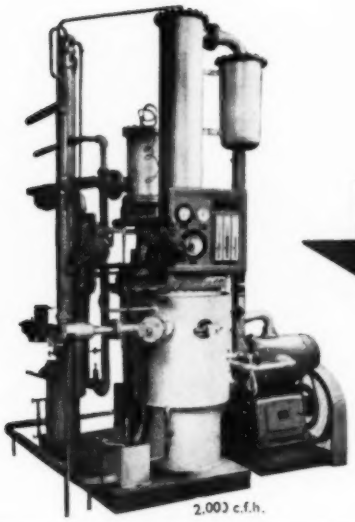

2,000 c.f.h.

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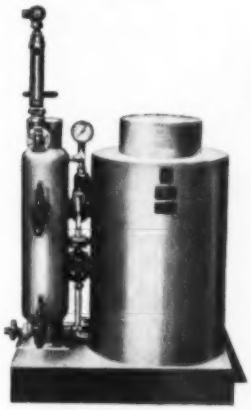
For bright treatment of stainless acid resisting and heat resisting steels, and for brazing and sintering generally.



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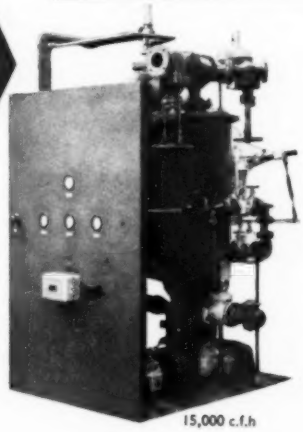

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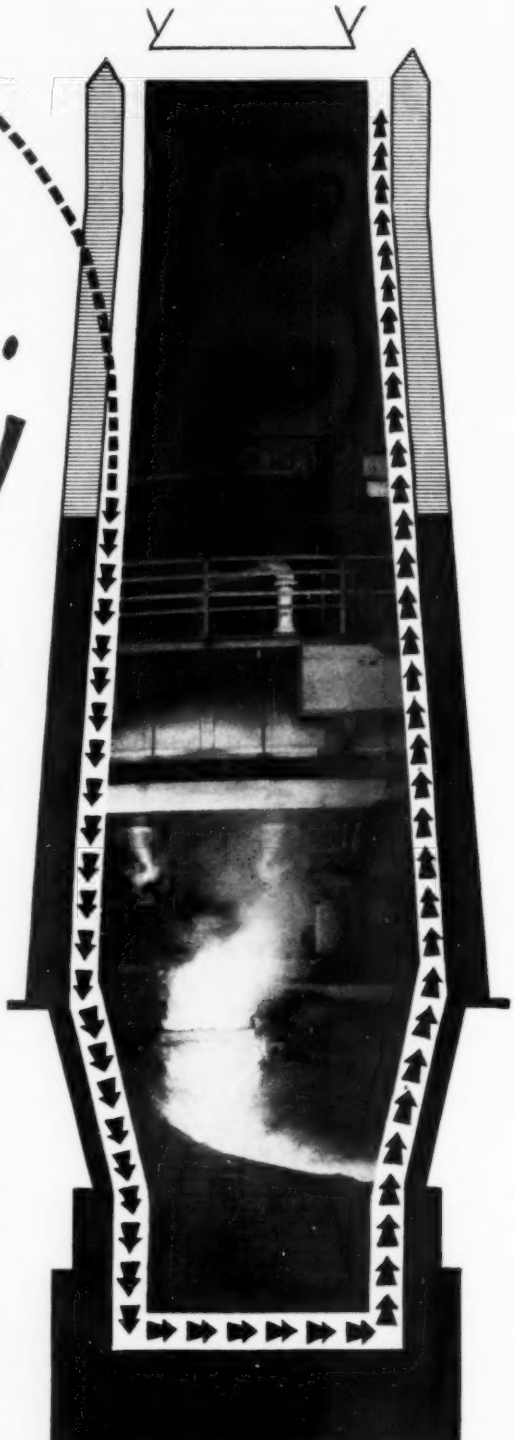

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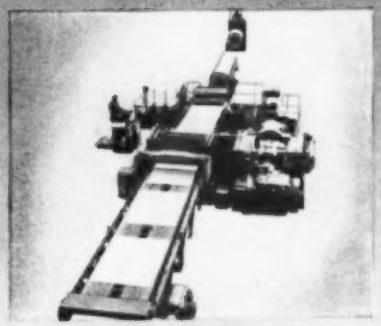

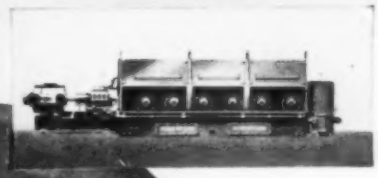

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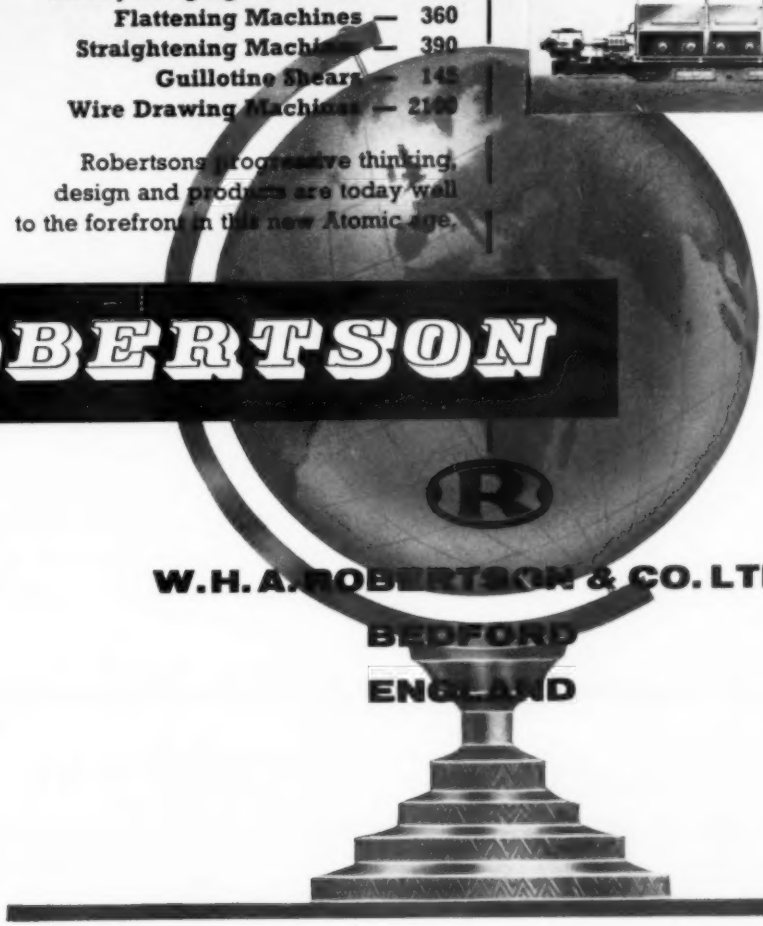
Robertsons progressive thinking, design and products are today well to the forefront in this new Atomic age.



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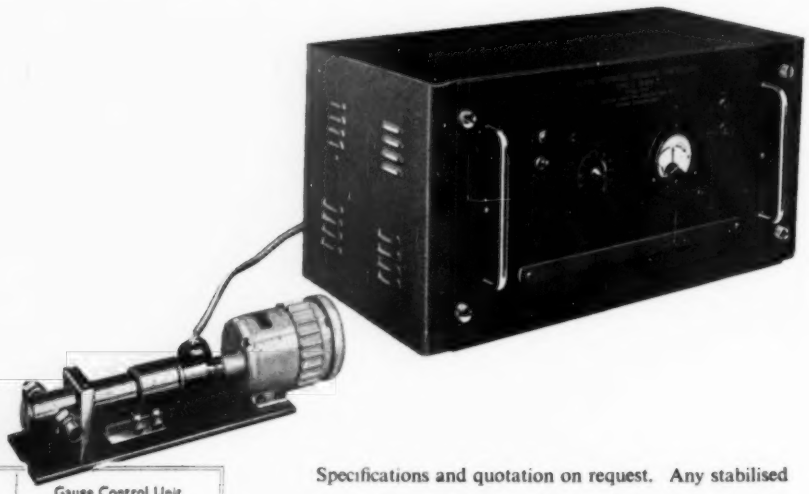

Pressure Range mm. Hg.	Type of Gauge Head	Gauge Control Unit
10^{-4} to 10^{-3}	G.I.	G.I, G.T.I, and P.O.A.C.E. All Types.
10^{-3} to 1	G.P.	G.P.I, etc.
10^{-3} to 100	G.A.	G.A, All marks
100 to Atmospheric	Pressure Transducer	Under development

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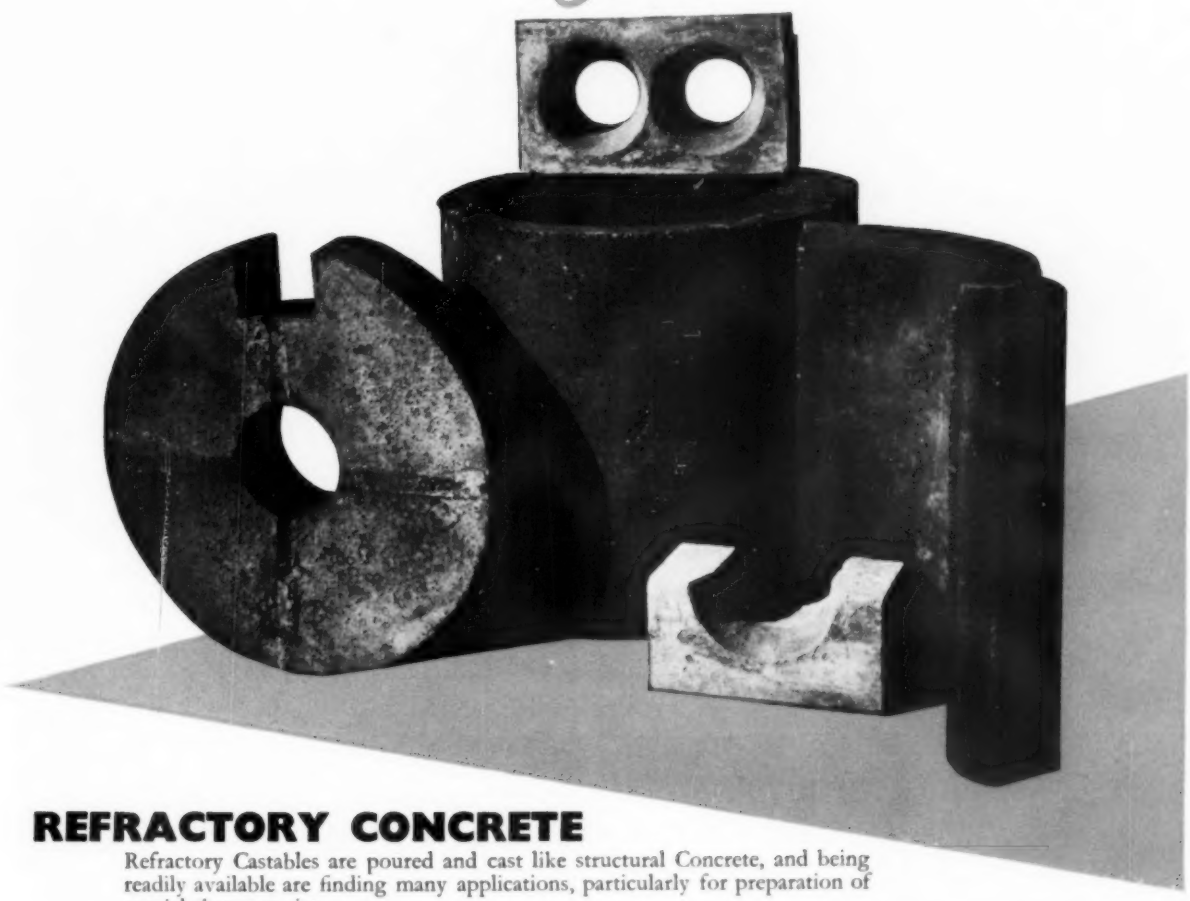

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Stein Super Refractory Concrete No. 16	Dry	+1750°C	Hydraulic	1200°C	1600°C	160
No. 17	Dry	+1750°C	Hydraulic	1200°C	1700°C	160
No. 18	Dry	+1750°C	Hydraulic	1200°C	1800°C	160
Stein Chrome Concrete	Dry	+1750°C	Hydraulic	1200°C	1500°C	180

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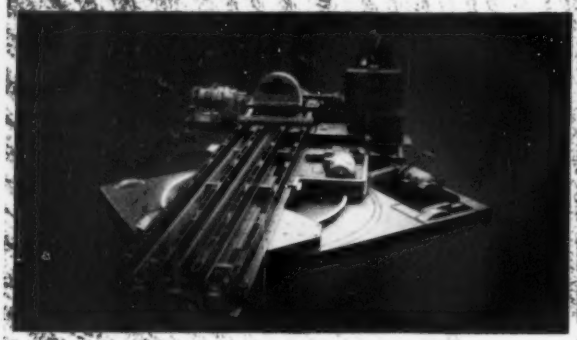

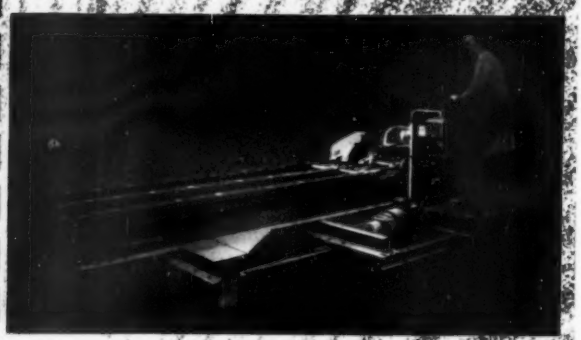

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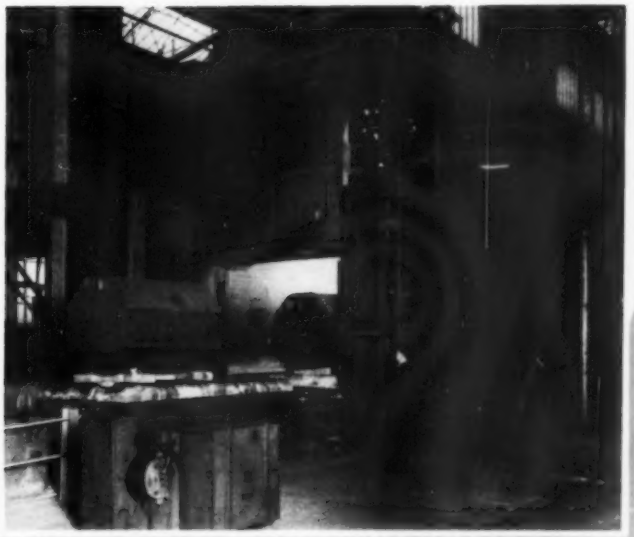

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- Forge and Heat Treatment Furnaces
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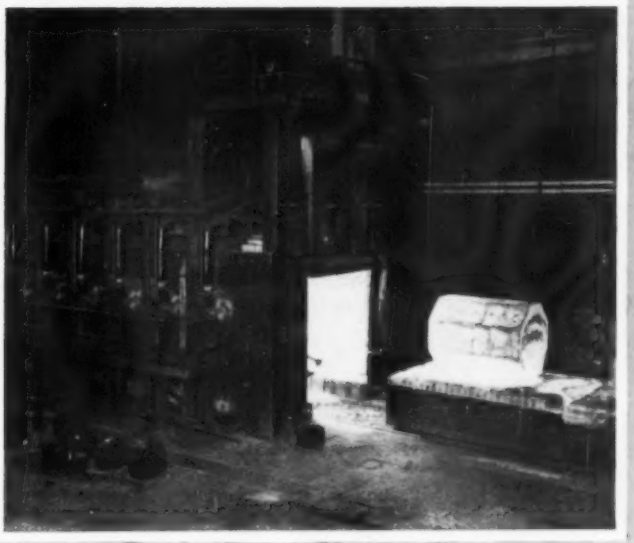
- Mould Drying Stoves
- Modern Lime Burning Kilns.



The illustrations are of the charging and discharging end of a Towns Gas Fired Furnace installed for The Chesterfield Tube Co., Ltd. This unit is for heating billets prior to piercing and is also suitable for heat treating miscellaneous items in the soaking section.

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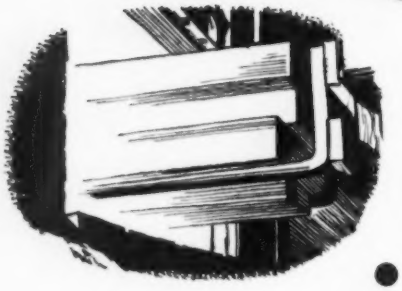
Research

Speed, efficiency, quicker handling and furnace charging and all-round saving in time and money—these are the benefits which the new T-shaped ALCAN* ingot have brought to the aluminium fabricators.

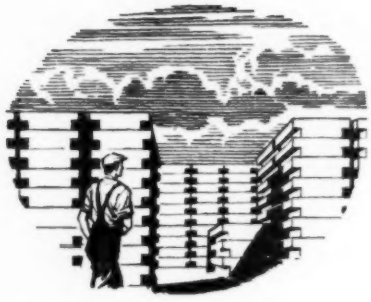
cuts an



This 'T' ingot saves storage space. 18,000 lb. of T-shape ingot have been safely stacked in an area suitable for only 10,000 lb. of the normal 50 pound ingot. Loading time is consequently cut. The new ingot is shaped like a flattened 'T' and is designed to fit squarely in the tines of a fork lift truck. Customers report that their loading time has been cut by 50%.

industry's

Produced by precision chill casting, this ingot is part of an active programme which aims at cutting an industry's costs. Whether your problem is casting, rolling, extruding, anodising or structural fabrication, the Aluminium Limited Group have the facilities to help you solve your problem.



costs

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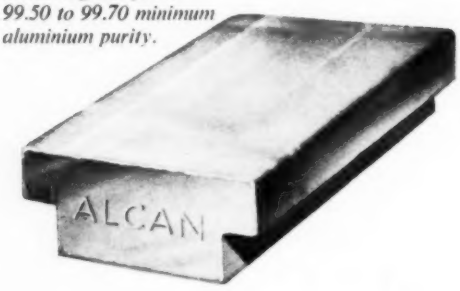
*ALCAN—*The Aluminum Company of Canada Ltd., principal producing company of the Aluminium Limited Group.*

The ALCAN 'T' Ingot.
Technical Details:
Weight: *1500 and 750 lb.*
Composition: *Alcan commercial metal in grade from 99.50 to 99.70 minimum aluminium purity.*



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VIM LEATHER "V" PACKINGS can be used for most installation designs and, because of the wide variety of impregnating compounds employed, these "V"s are suitable for oil, brine, water, aqueous solutions, air, oxygen and other gases. VIM "V"s help to keep production rates to schedule.

Technical advice on request.

Manufactured by the Leather Packings Division of

Edgar Vaughan & Co. Ltd.

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Other Vaughan Products :

Metal Cutting Oils, Drawing Compounds, Rust Preventives, Hydraulic Oils and Fluids, Special Lubricating Oils and Greases, Heat Treatment Oils and Salts, Industrial Cleaners, Fuel Oil Additives.

Works and depots at : Birmingham, Manchester Liverpool, Southall (Middx.), Bristol, Glasgow

Increased Thermal Insulation Efficiency with THERBLOC

THIS DATA SHOULD BE ON YOUR FILES

This Data Sheet gives the factors required to calculate the savings in heat loss obtainable with Therbloc mineral wool insulation used either by itself or supplementing insulating brick. Graphs and practical examples are included. May we send you a copy? Please phone Whitehall 0922-6 or the coupon is for your convenience.

STILLITE

Regd. Trade Mark

STILLITE PRODUCTS LTD.

15 Whitehall, London, S.W.1

Whitehall 0922-6

231 St. Vincent St., Glasgow, C.2 Tel: CENtral 4292

To STILLITE PRODUCTS LTD. 15 WHITEHALL, LONDON, S.W.1
Please send me Technical Data Leaflet No. 5B

NAME .....

POSITION .....

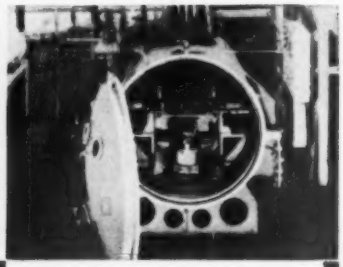
COMPANY .....

ADDRESS .....

5

. . . COULD A VACUUM FURNACE DO THE SAME FOR YOUR PRODUCTS?

Model 2555 Vacuum Induction Furnace with melting capacity of 50 pounds of steel. Other standard furnaces have capacities of 12 to 3,000 pounds.



Model 2705 Non-Consumable Arc Skull Furnace with a capacity of 50 pounds of titanium. Other standard vacuum arc furnaces have capacities of 8 to 10,000 pounds of titanium.

Metals for parts to withstand jet engine temperatures and stresses can be produced in vacuum furnaces. Such metals enable components to be made with fewer rejects. If your products need parts that operate under severe conditions or need high purity metals or alloys—a vacuum furnace will help you to produce them.

Wild-Barfield can supply equipment made to the designs of and tested by the unrivalled experience of the National Research Corporation who have built and operated more high vacuum furnaces than any other company in the world.

Write for details of the Wild-Barfield—NRC range of high vacuum plant.

WILD-BARFIELD—NRC EQUIPMENT INCLUDES:

VACUUM INDUCTION FURNACES
VACUUM ARC FURNACES
VACUUM RESISTANCE FURNACES
VACUUM ANALYSING EQUIPMENT
HIGH VACUUM DIFFUSION PUMPS
LABORATORY VACUUM FURNACES

NRC is the trade-mark of the National Research Corporation, registered in the United States Patent Office.

ELECTRIC WILD BARFIELD FURNACES

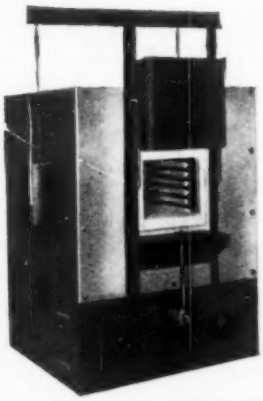
for all heat-treatment purposes

WILD-BARFIELD ELECTRIC FURNACES LIMITED

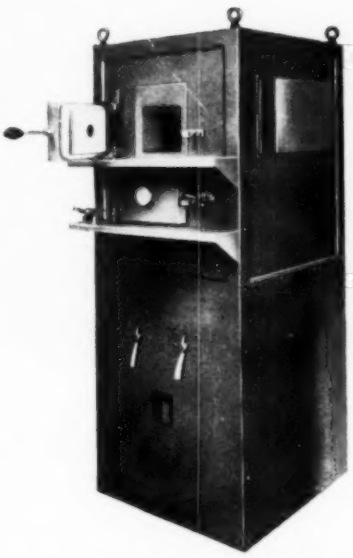
ELECFURN WORKS · OTTERSPOOL WAY · WATFORD BY-PASS · WATFORD · HERTS. Telephone: Watford 26091 (8 lines)

WB 84

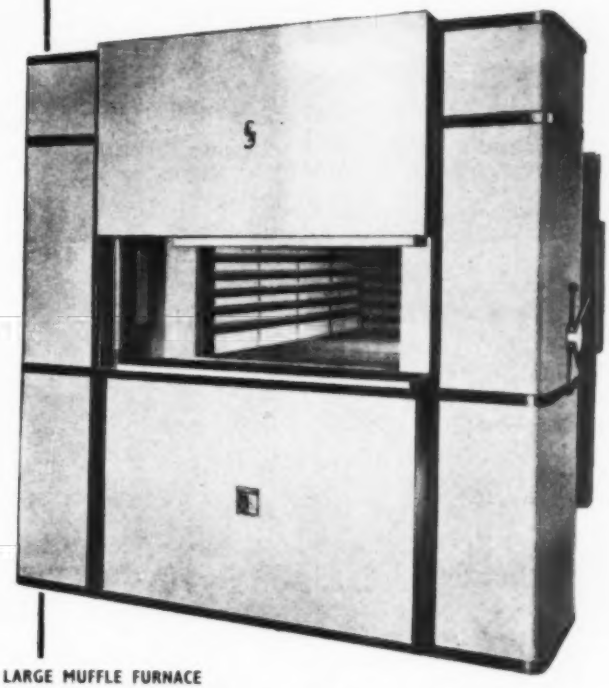
Electric Furnaces



BENCH MOUNTING FURNACE
Muffle 10in. x 7in. x 6in.



DOUBLE MUFFLE FURNACE
Each Muffle 1ft. 2in. x 7in. x 6in.



LARGE MUFFLE FURNACE
Muffle 5ft. 6in. x 3ft. 0in. x 1ft. 9in.

Here are illustrated a few of our range of Muffle Furnaces. We supply a large variety of furnaces for numerous purposes and will quote for a furnace to suit any specific requirements.

SILIT **HEATING RODS FOR HIGH TEMPERATURES**

SIEMENS-SCHUCKERT

(GREAT BRITAIN) LIMITED

FARADAY WORKS · GREAT WEST ROAD · BRENTFORD · MIDDLESEX

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BIRMINGHAM Tel. Midland 2082 CARDIFF GLASGOW Tel. Central 2635
MANCHESTER Tel. Chorlton 1467 NEWCASTLE Tel. 28617 SHEFFIELD Tel. 61564

Picture of a man . . .

. . . with all the answers on insulating bricks

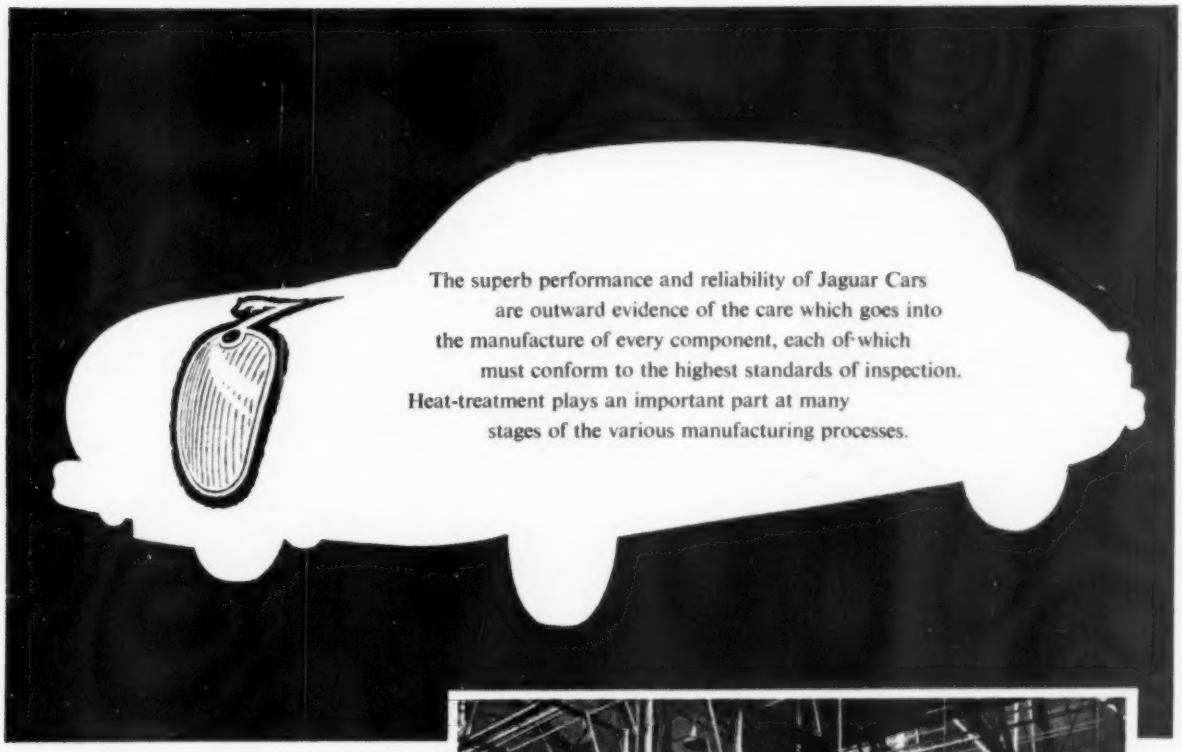
He is finding that the use of insulating bricks for more effective heat insulation has been a subject well worth looking into. Reading further he'll see that Newalls make a range of insulation bricks under the trade names "Nonpareil" and "Newparex" which are designed to cover heat insulation requirements up to 2012°F (1100°C). But why not read the catalogue yourself? Like the man in the advertisement, you'll find factual answers to all your queries.

Write to us for a copy of our
INSULATING BRICK CATALOGUE
which will be supplied free on request.

Newalls

NEWALLS INSULATION CO. LTD. *Head Office:* WASHINGTON, CO. DURHAM
A member of the TURNER & NEWALL ORGANISATION
Offices and Depots at LONDON, GLASGOW, MANCHESTER, NEWCASTLE UPON TYNE, BIRMINGHAM, BELFAST, BRISTOL & CARDIFF. *Agents and Vendors in most markets abroad.*

JAGUAR AND G.W.B.


The superb performance and reliability of Jaguar Cars
are outward evidence of the care which goes into
the manufacture of every component, each of which
must conform to the highest standards of inspection.
Heat-treatment plays an important part at many
stages of the various manufacturing processes.

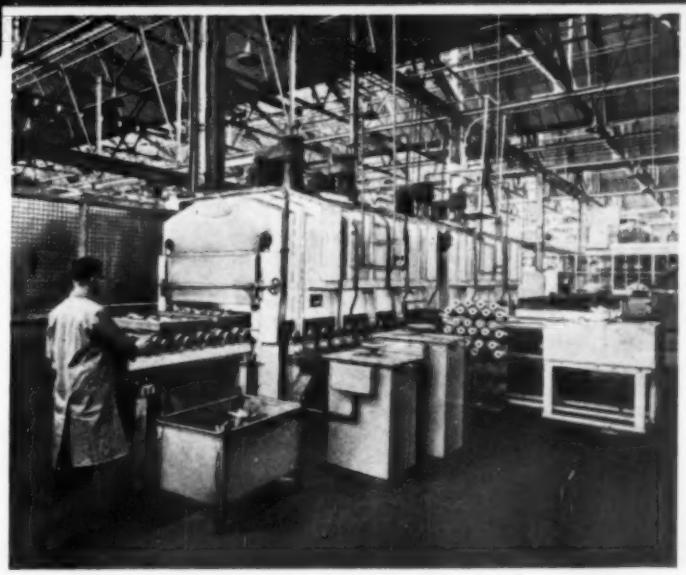
The latest addition to the heat-treatment shop at Jaguar Cars Limited is a G.W.B. electrically heated Roller Hearth Furnace specially designed to carry out normalising, cyclic annealing and stress relieving a variety of components.

SPECIAL FURNACE DESIGN

The unusual multi-purpose requirements have resulted in an installation in virtually two sections. (1) High temperature (950°C) furnace, followed by (2) forced draft cooling section, and finally, (3) a 650°C heating chamber.

APPLICATIONS

Normalising:	Welded components slow cooled from 900°C.
Cyclic annealing:	Gear forgings heated to 950°C, cooled to 550°C and re-heated to 650°C.
Stress Relieving:	Partly machined forgings such as crank shafts and gear blanks stress relieved between 550 and 650°C, and cooled to 200°C in the final 8'6" long cooling chamber.



Over 25 years experience in electric furnace design at your disposal.

GWB

G.W.B. FURNACES LTD.

P.O. BOX 4, DIBDALE WORKS, DUDLEY, WORCS. *Telephone: Dudley 4284/5/6/7 and 5081/2/3/4/5*

Associated with: Gibbons Bros. Ltd., and Wild-Barfield Electric Furnaces Ltd.

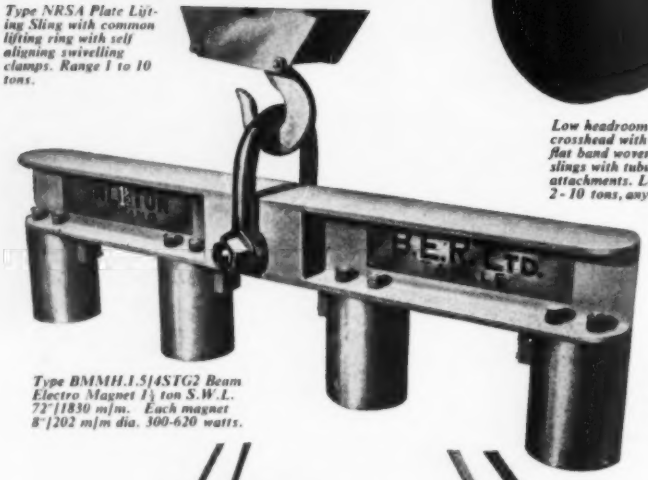
GWB 108

B.E.R.L Specialised Lifting Tackle

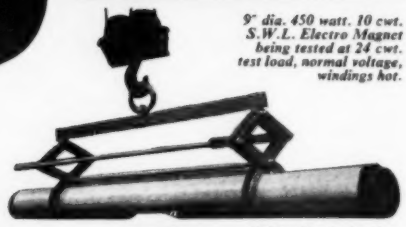
Vertical cylindrical specified diameter lifting device.

Horizontal cylindrical specified diameter lifting device, also supplied with special clamp faces for handling ground diameters.

Type NRSA Plate Lifting Sling with common lifting ring with self aligning swivelling clamps. Range 1 to 10 tons.



Low headroom all steel crosshead with pair of flat band woven wire slings with tubular end attachments. Load range 2 - 10 tons, any diameter.

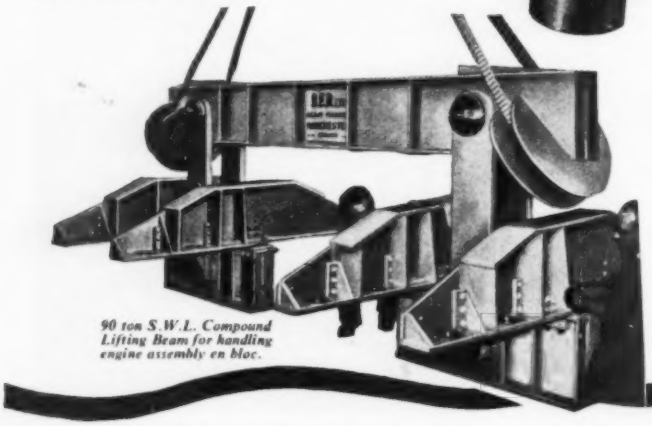


9" dia. 450 watt. 10 cwt. S.W.L. Electro Magnet being tested at 24 cwt. test load, normal voltage, windings hot.

Rubber lined split clamp lifting device for hot semi-plastic loads.

Type BMMH.I.5/4STG2 Beam Electro Magnet 1½ ton S.W.L. 72"/1830 m/m. Each magnet 8"/202 m/m dia. 360-620 watts.

Ingot lifting device for lead or copper etc., to any size and rating required.



90 ton S.W.L. Compound Lifting Beam for handling engine assembly en bloc.

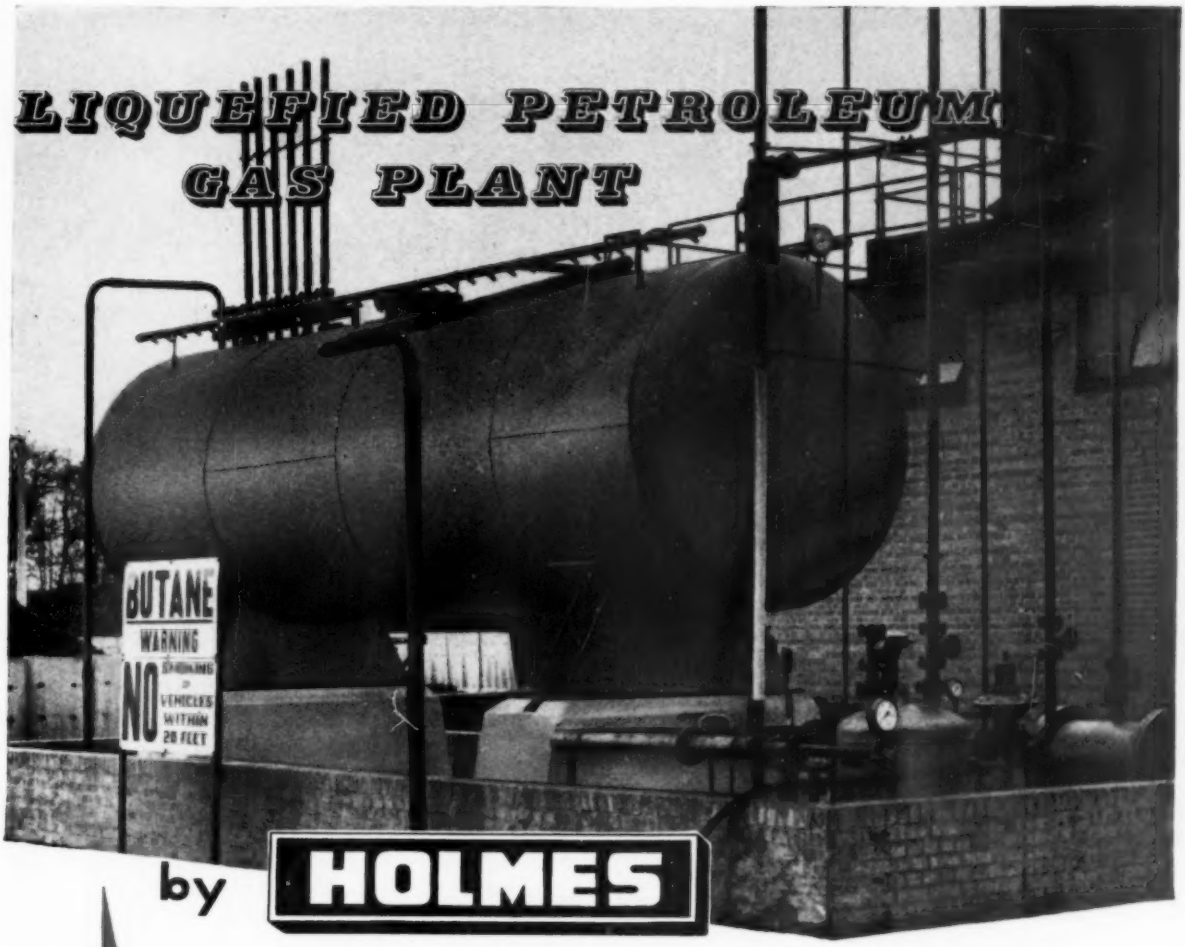
The BERL service is offered to all users of lifting tackle and illustrated above are some of the lifting devices from our extensive range. When dealing with your load raising problems remember BERL hold the answers.

B.E.R.L

Better Equipment for Raising Loads

BRITISH ELECTRICAL REPAIRS LIMITED, EMPIRE HOUSE, CHARLOTTE ST., MANCHESTER 1

dm BER.89



by **HOLMES**

The Holmes L.P Gas Plant illustrated above was designed to meet an increased demand for gas at the Luton Works of Messrs. Vauxhall Motors Ltd. When the output of existing producer gas plants is at a maximum, further thermal requirements the various furnaces are supplied automatically by the controlled admission of butane vapour into the producer gas stream.

MANUFACTURED GAS ENRICHMENT
BUTANE/AIR FOR TOWNS GAS SUPPLY
PRODUCTION OF CONTROLLED ATMOSPHERES
SPACE HEATING · GAS CARBURISING
PEAK LOAD PLANT · STAND-BY PLANT

Shell-Mex and B.P. Gases Ltd., are suppliers of Liquefied Petroleum Gases. Commercial butane and propane are gases of high purity, consistent quality, low sulphur content and high calorific value. Bulk deliveries can be made by Shell-Mex and B.P. Gases Ltd. to all parts of Great Britain with their large fleet of tankers.

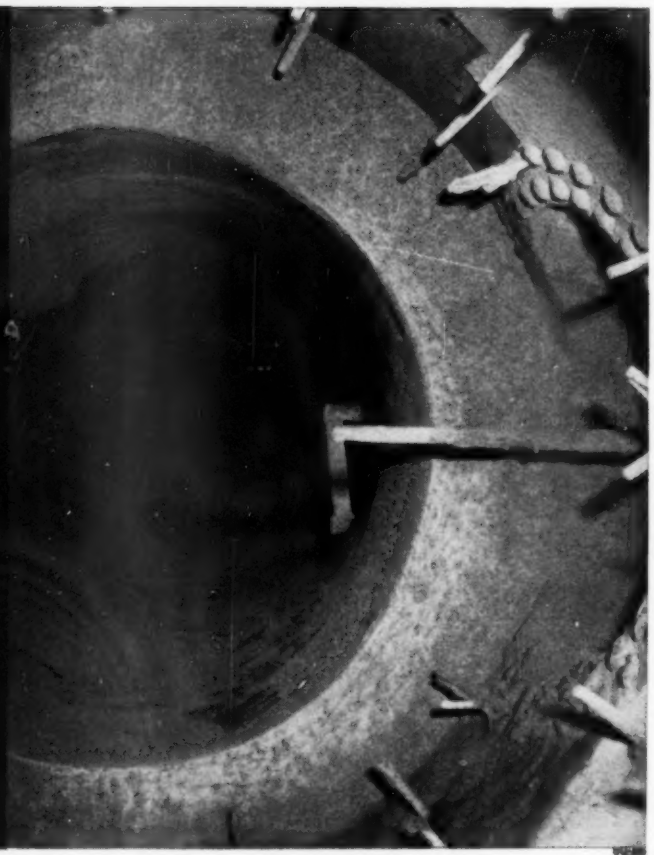
W. C. HOLMES & CO. LTD
Gas Cleaning Division

TURNBRIDGE, HUDDERSFIELD, LONDON · BIRMINGHAM ·

Technical Associates *Woodall-Duckham (Australasia) Pty. Ltd., 340 Spencer Street, Melbourne C.1*

C9388

Tri-Mor Plastics and Castables make installation Easier Quicker and Cheaper



Bustle main of Queen Victoria Blast Furnace showing 'gunned' lining in Tri-Mor Dense 'Guncrete'. (Inside diameter of shell 5 feet. Thickness of 'Guncrete' lining 9 inches).
Photograph by courtesy of the Appleby-Frodingham Steel Co. (Branch of the United Steel Companies Ltd.).

TRI-MOR GRADES

TRI-MOR *Standard Castable*

A medium texture refractory having negligible shrinkage up to 1,350 C. Suitable for casting special shapes or for monolithic structures. Limiting service temperature 1,350 C.

TRI-MOR *High Strength Castable*

A similar refractory to Tri-Mor Standard Castable, but specially developed to have very high mechanical strength over the lower temperature range. Maximum service temperature 1,250 C.

TRI-MOR *High Temperature Castable*

Suitable for face temperatures up to 1,600 C; has an extremely high resistance to thermal shock; used for cast in situ monolithic structures and for pre-cast refractory shapes; can be applied with a cement gun.

TRI-MOR *High Temperature Mouldable*

A plastic refractory for use up to 1,650 C: low shrinkage and a high resistance to spalling. Supplied mixed to the correct consistency for installation.

TRI-MOR *Dense "Guncrete"*

A hydraulic setting refractory with a maximum service temperature of 1,300 C. It has a high resistance to abrasion. Designed for application by cement gun, but can be trowelled.

TRI-MOR *Insulating Castable*

An insulating castable for maximum service temperatures of 1,200 C; low thermal conductivity is its main feature.

TRI-MOR *Insulating "Guncrete"*

Similar to Tri-Mor Insulating Castable but for application by cement gun.

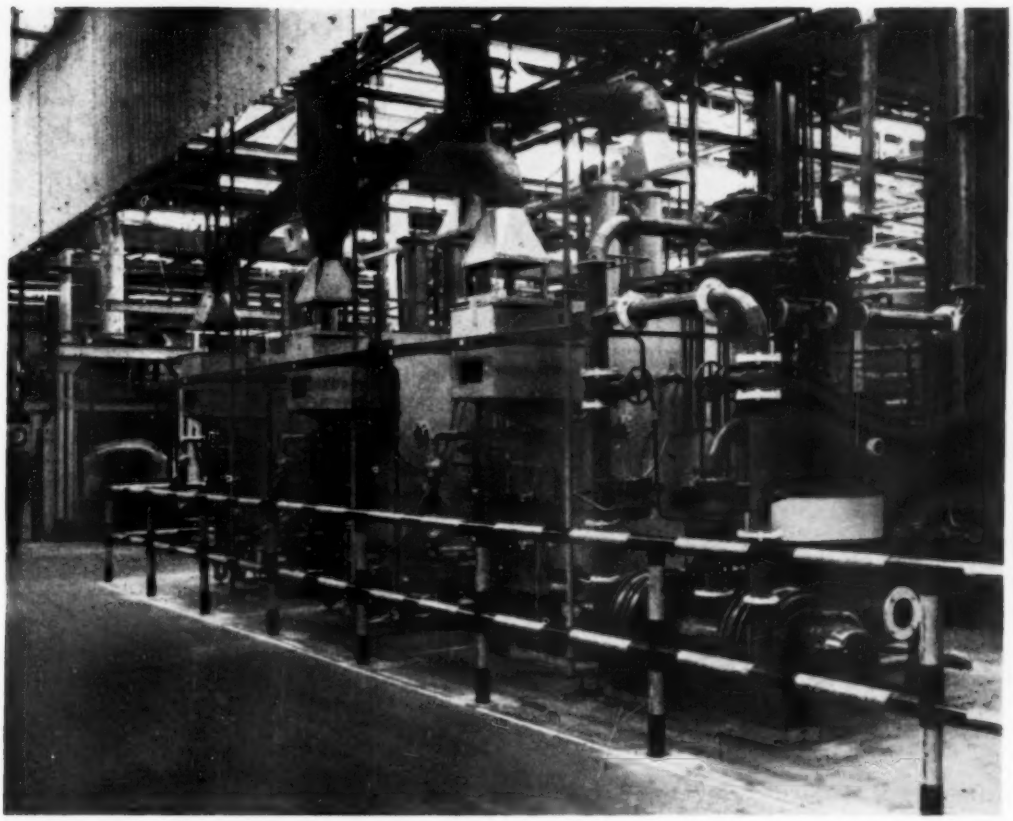
Full details of each grade are available on request.

MORGAN Refractories Ltd

For further information write to: MORGAN REFRACTORIES LTD NESTON, WIRRAL, CHESHIRE. TEL: NESTON 1406 NE 143

PERFORMANCE *PROVES–*

THE ECONOMY OF QUALITY



ENDOTHERMIC GAS GENERATING UNITS AT VAUXHALL MOTORS LTD.

THE VAUXHALL 'VICTOR'

In accordance with their usual policy that only the best is good enough Vauxhall choose Gas Generating Units backed by 25 years' experience for their Luton and Dunstable extensions.

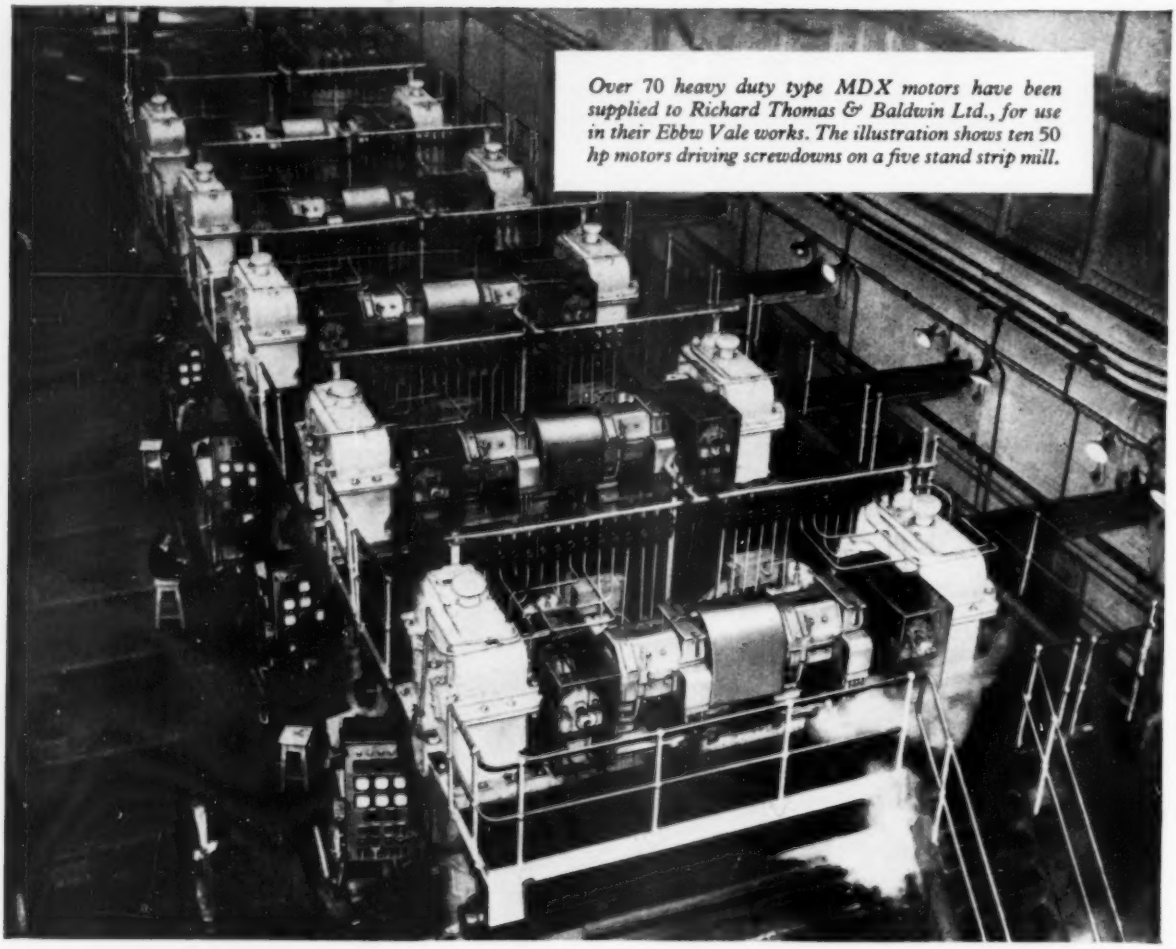
The endothermic gas requirements at Luton are supplied from five " RX " units and three similar units are installed at Dunstable.

" RX " Units installed or on order have a total gas capacity of over 66,000 cubic feet per hour.

These units offer the most in all-round advantages—in uniform quality gas of relatively high carbon potential easily controlled.

BRITISH FURNACES LIMITED—CHESTERFIELD

ASSOCIATED WITH SURFACE COMBUSTION CORPORATION · TOLEDO — U.S.A.

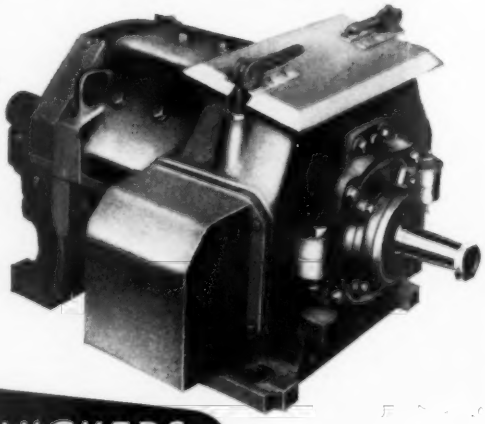


Over 70 heavy duty type MDX motors have been supplied to Richard Thomas & Baldwin Ltd., for use in their Ebbw Vale works. The illustration shows ten 50 hp motors driving screwdowns on a five stand strip mill.

All motors here are type MDX

Metrovick type MDX motors have been specially designed to operate under the arduous conditions of iron and steel works. Their strength and reliability, and the exceptionally low inertia of the rotating parts make these machines ideal for driving a wide range of steelworks equipment. The use of mica and glass insulation suitable for high temperature operation enables the motor to withstand heavy overloads.

Available totally enclosed, up to 200 hp, or self-ventilated, up to 250 hp.



METROPOLITAN-VICKERS

ELECTRICAL CO. LTD. TRAFFORD PARK MANCHESTER 17

An A.E.I. Company

Metrovick Motors for Trouble Free Service

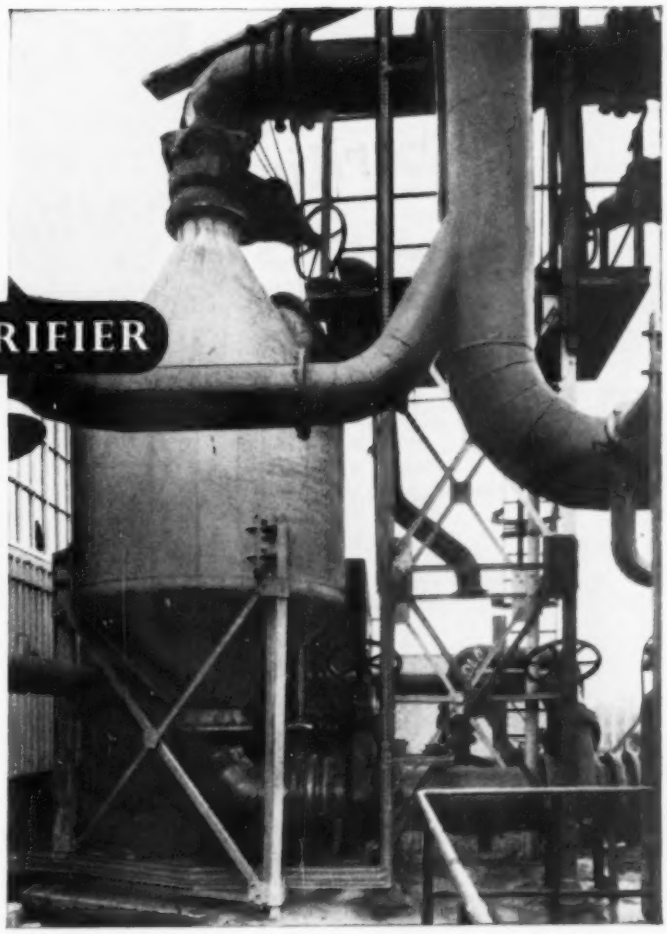
1/570

This large

deoxo

CATALYTIC GAS PURIFIER

is now in use at British Oxygen Gases Ltd at Middlesbrough



This Deoxo purifier, model D to treat 176,500 c.f.h. of gas has recently been put on stream at British Oxygen Gases' new air liquefaction plant for the removal of residual oxygen from a part of the nitrogen stream. It is capable of removing oxygen impurities from nitrogen gas down to a remaining impurity of less than one part per million (0·0001%). 'Deoxo' models can be supplied to purify from 5 to 1,000,000 c.f.h. of hydrogen, nitrogen and other gases.

Write for this Booklet giving full details of the 4 types of 'Deoxo' purifiers now available

The "Deoxo" Process provides for the catalytic hydrogenation or oxidation of certain gases which hitherto has been impracticable from a production standpoint because of cost factors or control problems. In other cases it has been impossible to obtain the extreme purities that are now achieved by the use of Baker Catalysts.

All standard models can be supplied in a wide range of capacities operating at any pressure up to 50 lbs. per sq. in. Special units to meet specific conditions as to pressure drop, physical size, capacity, or operating pressure can be provided.

ENGELHARD INDUSTRIES, LTD. BAKER PLATINUM DIVISION

52 HIGH HOLBORN · LONDON · W.C.1 · CHAncery 8711

For Hanging in critical positions

'Position' is extremely important to artists but in steel-making the problem is to decide *the type of refractories to use* in critical positions. In open hearth furnace practice, selection is simplified by the availability of the newly developed GR 'Ferroclad' metal cased bricks fitted with stainless steel tabs or saddles for easier suspension.

This method of suspended construction eliminates many of the causes of roof and end failure and is a great advance on the traditional sprung roof. The GR Technical Service Department will be pleased to tell you more about 'Ferroclad' and advise on your specific refractory requirements.

Everything in Refractories

GR

GENERAL REFRACTORIES LIMITED · GENEFAX HOUSE · SHEFFIELD 10 · TELEPHONE: SHEFFIELD 31113

392

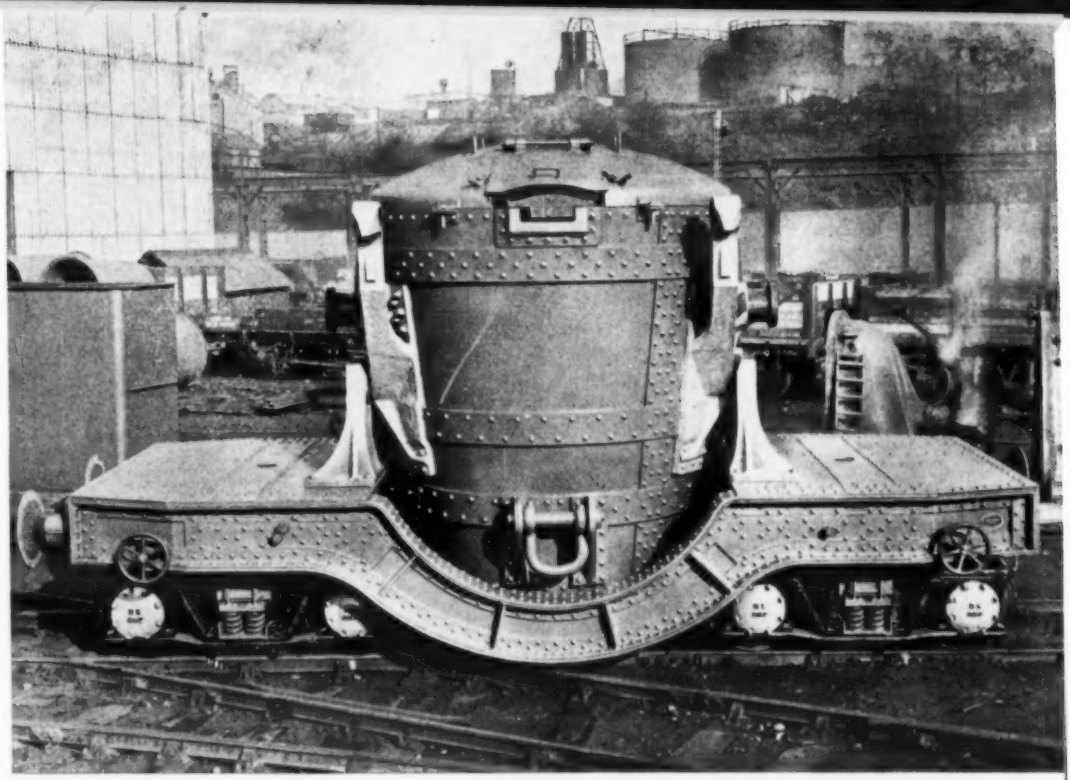
NEWTON CHAMBERS

Steelworks equipment

NEW metals and alloys—even new industries—offer an exciting challenge to the engineer to-day. A challenge which is accepted with confidence by the Engineering Division of Newton Chambers, who are now better equipped than ever before to supply the highest quality steelworks plant and equipment.

The new extensions to our constructional shops allow for the handling of the heaviest fabrications and include facilities for welding to Class 1 standards.

Newton Chambers are one of the largest suppliers of ancillary plant to the steel industry. Recent contracts include ladles of 275-tons capacity for John Summers & Sons, Ltd., Colvilles, Ltd. and ingot castings cars for the Steel Company of Wales.



ABOVE: *60-ton capacity short pour ladle and carriage supplied to Skinningrove Iron Co. Ltd.*

BELOW: *Ingot casting cars supplied to The Steel Company of Wales.*

ENGINEERS OF PROGRESS

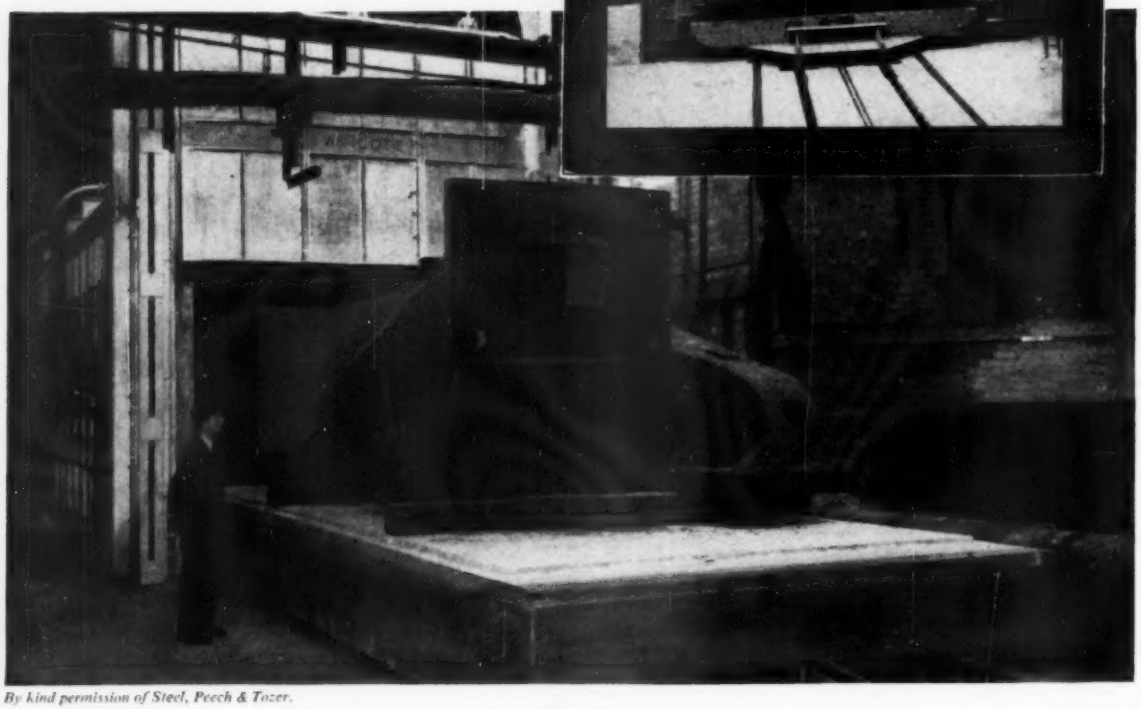
Newton Chambers ENGINEERING DIVISION

NEWTON CHAMBERS AND COMPANY LIMITED,
THORNCLIFFE, SHEFFIELD.

345048

Stress Relieving Furnaces

We have a wide experience in the design and installation of large bogie hearth furnaces for the general heat treatment of fabrications' alloy steel castings and ingots.
Capable of taking loads of up to 250 tons they can be fired by towns gas, clean producer gas or oil and with full instrumentation a minimum temperature variation is possible throughout the chamber.



By kind permission of Steel, Peech & Tozer.

WINCOTT FURNACES

G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND
Telegrams: WINCOTT, SHEFFIELD. *Telephone: 20211/2*

SBW.19

PYROSCALE EDGEWISE INDICATORS AND PYROCOUPLES

Pyroscale Edgewise Indicators are designed for use on Furnaces, Salt and Metal Baths, Ovens and Infra-red tunnels, Diesel Engines, Boilers and Power Plant, Diecasting Machines, Injection moulding machines and other applications where accurate temperature measurement is vital.

They are available for wall and flush panel mounting in calibrated scale lengths of 4", 6" and 8" and have a knife edge pointer with anti-parallax mirror, which ensures accurate readings. They combine robustness and accuracy to give a high quality instrument at reasonable cost.

- PYROSCALE EDGEWISE INDICATORS
- PYROSCALE PORTABLE INDICATORS
- PYROSWITCH MULTI-POINT PYROMETERS
- PYROCOUPLES
- FOUNDRY PYROMETERS
- INDICATING PYROMETERS CONTROLLERS
- MECHANICAL PYROSTAT CONTROLLERS
- ELECTRONIC PYROSTAT CONTROLLERS

Cut out this advertisement and indicate which of the above leaflets you would like to receive.

A variety of Pyrocouples are manufactured and it is of primary importance that the most suitable arrangement is selected to combine adequate response and reasonable life, in accordance with the operating conditions of temperature and atmosphere.

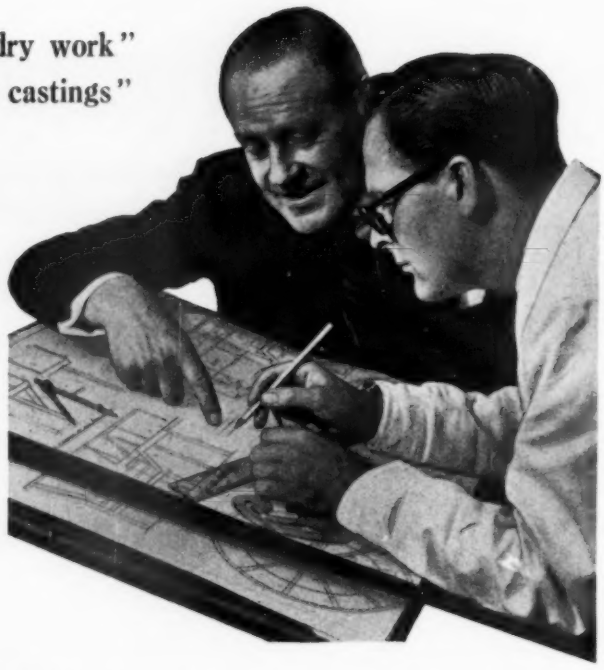
Automatic Temperature Control Equipment, mechanical or electronic type, is also available.

THE INDUSTRIAL PYROMETER CO. LTD

Gooch Street, Birmingham, 5

Phone: MIDland 3511-2 Grams: Ipcometer Birmingham 5

"This calls for very high quality foundry work"
"It calls for WILLAN quality steel castings"



Is the problem a limited run of high quality steel castings ? Willans are the people for that job. They manufacture to the highest standards in all alloy, stainless and heat-resisting steels and use extensively non-destructive inspection testing. Castings can be supplied in any weight from a few ounces to 6 cwts. They can also melt and cast in a vacuum in special cases. If the accent is on quality, rather than on quantity, call in Willans at once !

G. L. WILLAN (CASTINGS) LTD

Sussex Street, Sheffield, 4. *Telephone* : 24211

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refractories

for all types of furnaces

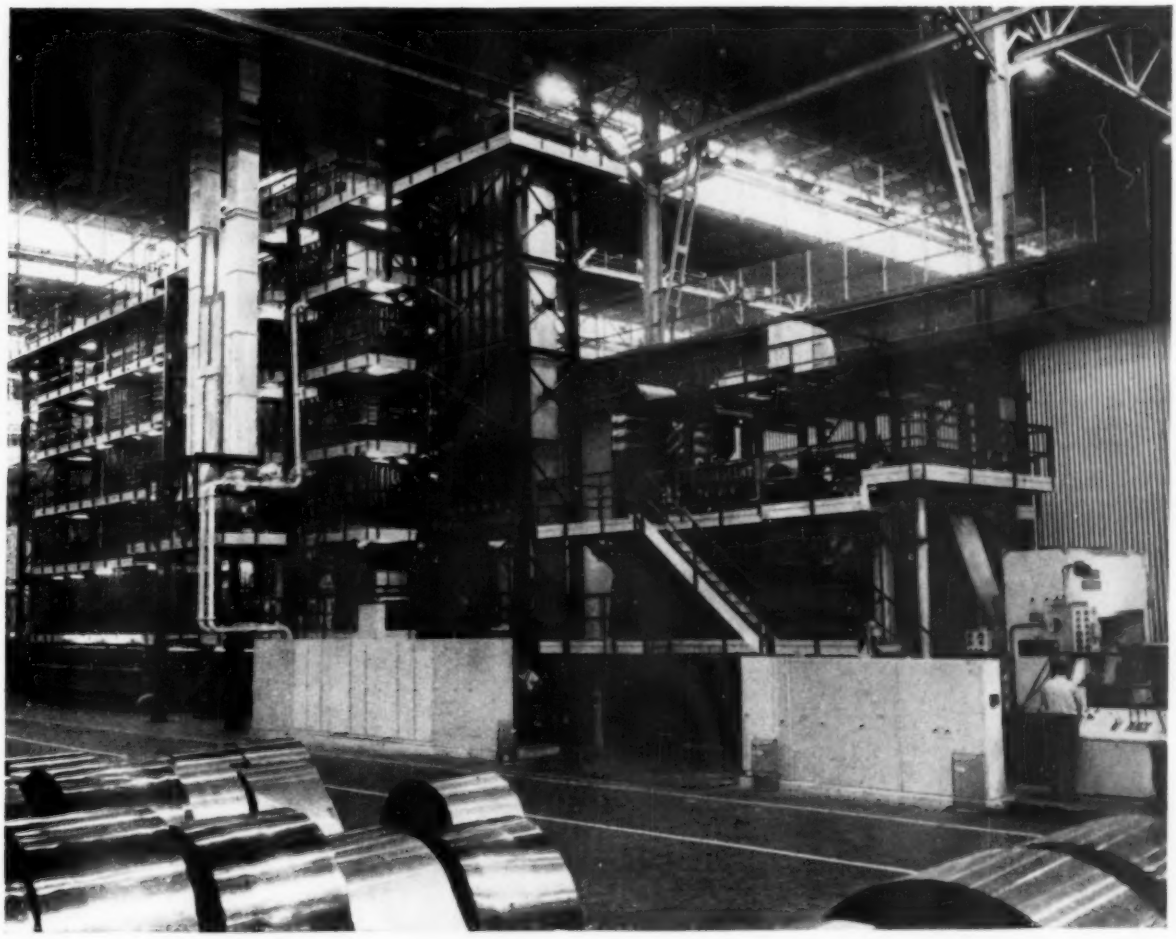
SEMI SILICA • STOURBRIDGE FIREBRICK • ALUMINOUS FIREBRICK • HIGH ALUMINA • SILLIMANITE • FIRE BRICK INSULATION • HIGH TEMPERATURE INSULATION • JOINTING MATERIALS • AIR-SETTING CEMENTS • REFRACTORY CONCRETES • RAMMING COMPOUNDS

Technical details and prices of all grades available on request.

E. J. & J. PEARSON LTD. FIREBRICK WORKS, STOURBRIDGE

Telephone : Brierley Hill 77201

EJ&JP



Photograph reproduced by courtesy of The Steel Company of Wales Ltd.

five customers or fifty million

At some time or other everyone needs the tinplate which is annealed in this furnace. Few will have direct contact with INCANDESCENT who built the plant, but the same skill and ability which produced this, Europe's first continuous tinplate cleaning and annealing line, is at their disposal for all heat treatment problems.

INCANDESCENT

THE INCANDESCENT HEAT CO. LTD., SMETHWICK, ENGLAND

13/5A/59

where and when they're wanted

SILICA CEMENTS
GUNNING COMPOUNDS
STEEL MOULDER'S COMPOSITION
HIGH FREQUENCY FURNACE LININGS
SILICEOUS LADLE JOINTING

Every day Dyson's are solving fresh problems as they keep pace with the continuously increasing demand for stronger and better refractory materials for Iron & Steel industries.

DYSON REFACTORIES

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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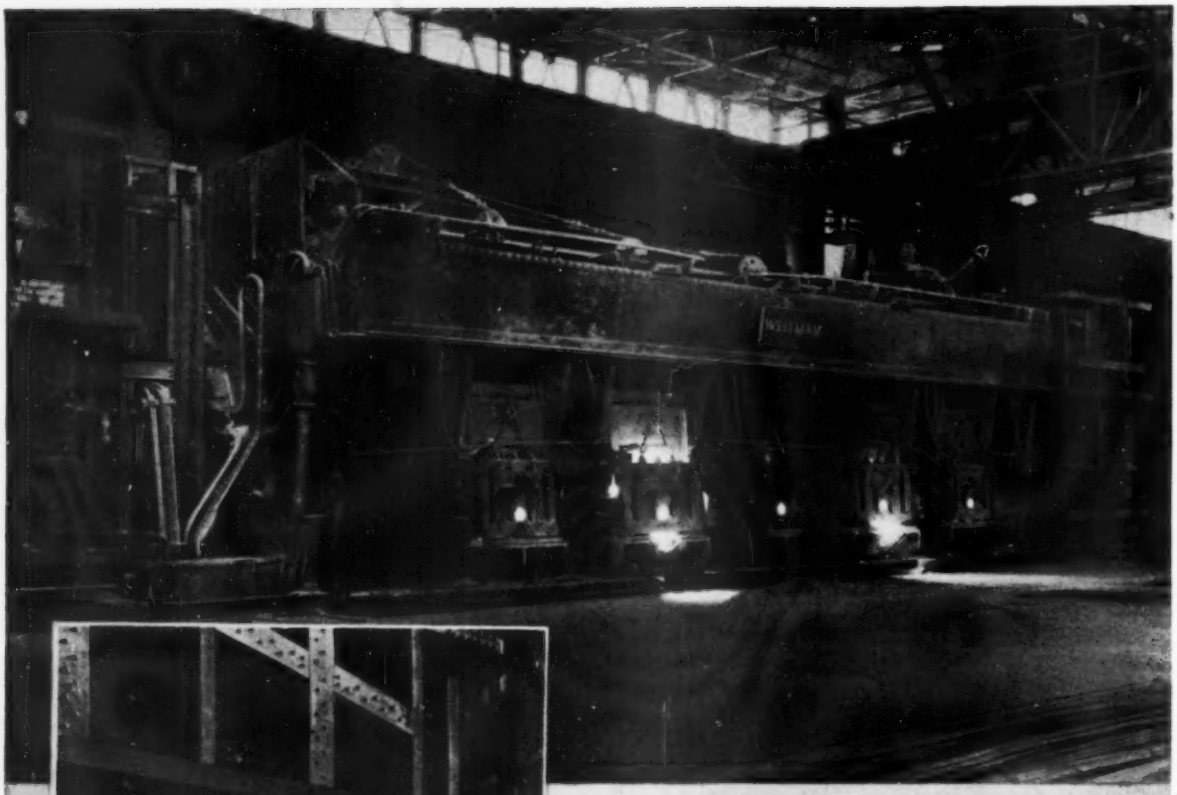

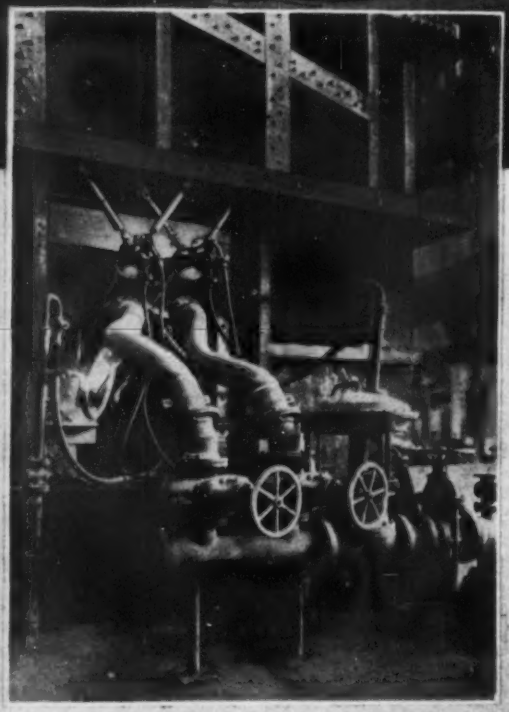

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

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Research and Technical Institutions

THE small number of post-graduate research students in technical institutions was deplored by Sir Harry Melville, K.C.B., F.R.S., Secretary of the Department of Scientific and Industrial Research, in his address at the Annual General Meeting of the Association of Technical Institutions, on February 27th, 1959. In view of the increasing importance of the technical institutions in the training of much-needed scientists and technologists, we believe that Sir Harry's remarks are likely to be of interest to many of our readers, and that they could usefully be presented here. During the course of his address, he said :—

"The D.S.I.R. Research Studentship is an award which until a few years ago went under the more prosaic title of "D.S.I.R. maintenance allowance." These awards are intended to provide a training in methods of research for young persons holding good honours degrees or acceptable alternative qualifications. This year we hope to make nearly 800 new awards of this sort, and the total number current after October next is likely to be about 1,800. In each of the next few years, we are likely to increase the number of new awards we make annually by about 10% to reflect the growing output of scientists and technologists.

"When we first started making these awards soon after D.S.I.R. was set up during the first World War, a number of the older technical colleges came to us for this form of help. I was surprised to learn that, although in 1922 we awarded only 156 Research Studentships in all, the number we awarded for tenure in technical colleges was greater than the number awarded in 1956. In fact, in 1922 the technical colleges took up nearly 10% of our awards, a figure which dropped to about 1% during the 1930's, but which last year I am glad to see rose to nearly 7%.

"It would be idle to deny that the attractions of the universities for the academically brilliant youngster are very strong, and that as a consequence a large proportion of all students suited to postgraduate research is likely always to come from the universities, and also to wish to receive its postgraduate training there. But I think other factors may be at work aggravating this tendency, for too many of the better research students seek their postgraduate training in the universities rather than elsewhere. Perhaps the universities have an attraction which other institutions are only slowly acquiring. Perhaps also the Ph.D. degree, which the university can offer its internal students, provides an attraction which is distorting the distribution of research students in ways that are not in the nation's interest. In some occupations the Ph.D. may have a cash value, and also in the minds of many young people the title of "Doctor" may make some appeal to a very natural streak of human vanity. Other establishments specialising in certain branches of technology and science (for example many technological institutions, the research associations, and D.S.I.R.'s own stations) can offer a valuable research training, but no doctorate as a hall-mark of success in this training (except to the London graduate able to work for his Ph.D. externally). We must give attention to ways of encouraging students to take their research qualifications in a wider range of institutions than at present. It remains to be seen whether the newly-created Hives research qualification of "Membership of the College of Technologists" will provide an award as popular as the Ph.D.

"The Postgraduate Training Grants Committee of our Research Council includes amongst its members Dr. Venables, the Principal of the Birmingham College of Advanced Technology. But even before Dr. Venables was invited to join this Committee as its expert on the affairs of technical institutions, I can assure you (for as a former university professor, I was at one time the Chairman of a D.S.I.R. forerunner of the present Committee) that D.S.I.R. has always treated applications from technical colleges every bit as sympathetically as it does those from any university. What has often disappointed us has been the small number of students of research calibre who have chosen technical institutions for their training, and whom you have been able to recommend to us.

"Therefore we feel that the distribution of our awards could be improved, and the obligation on us to seek ways of doing this has become stronger now that in England and Wales we have almost a monopoly for giving postgraduate awards in science and technology from public funds. 1956 was the last year in which the Ministry of Education and the local education authorities in England and Wales, as well as D.S.I.R., made these awards, and now, with an increased number at our disposal, we do so virtually alone. This rationalisation has produced a number of advantages, and from what I hear as I move about outside the Department, the new arrangements are on the whole well liked. But I do appeal to the technical institutions to make every endeavour to attract research students of a calibre that qualifies them to take up the many awards we are now in a position to offer for your use. At an advanced level, good teaching and research go hand-in-hand, and I think we may expect a snow-ball effect as soon as a rise in research effort in the technical colleges raises the esteem in which their research training is held by graduates, and vice versa.

"I should like to take this opportunity to remind you that we do not insist upon a candidate for our research studentship holding a good honours degree. There are alternative qualifications in which we accept sufficiently good performances in place of a degree (though for the present we have decided it might be invidious and

embarrassing to formulate the acceptable alternatives and levels in each of these precisely enough for us to publish a list.) However, we have decided to accept the new Diploma in Technology for our Studentships, and I hope that the staff of technical institutions will help us to make this fact widely known.

"In 1957 we awarded for the first time a D.S.I.R. Studentship of a new sort—the so-called Advanced Course Studentship—which is intended to maintain students taking postgraduate courses of instruction other than in methods of research. In the universities, this award enables students to take courses for master's degrees, postgraduate diplomas and the like, but so far very few of the technical institutions have taken advantage of the new scheme. Dr. Venables is Chairman of the Sub-Committee which is looking after our new award, and this slow response must be a matter of concern to him. Perhaps again the lack of a well-known hall-mark for students who have successfully completed a postgraduate course at a technical institution is one of the contributory difficulties.

"While I am speaking of studentships, I should like to take the opportunity to mention briefly that we are now trying to encourage young science graduates and engineers to spend at least one year of their postgraduate training abroad. Our objects in doing this, beyond providing postgraduate training, are to mix promising British postgraduate students with those of other countries; to enable them to work in overseas laboratories; and also to help them benefit more generally as human beings from the interest and stimulus of study abroad. We have also recently announced that D.S.I.R. will administer in this country a scheme of science studentships and fellowships for N.A.T.O., which will encourage international exchanges; and there is on the stocks a Commonwealth Scholarship scheme, of which you are likely to hear more in the future."

Meeting Diary

16th March

Sheffield Society of Engineers and Metallurgists. "The Conversion of a High-Lift Blooming Mill to a Universal Slabbing Mill," by C. E. H. Morris and R. N. Dale. **Joint Meeting with Sheffield Metallurgical Association.** The University Building, St. George's Square, Sheffield. 7.30 p.m.

17th March

Institute of Metals, South Wales Local Section. Annual General Meeting, followed by "A General Review of Current Research Work in the Metallurgy Department, University College, Swansea," by Professor H. O'Neill. Dept. of Metallurgy, University College, Singleton Park, Swansea. 6.30 p.m.

Sheffield Metallurgical Association. "Refractories Usage in Steelmaking Abroad," by C. S. Hedley. **Joint Meeting with the Refractories Association of Great Britain.** B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

18th March

Institute of Welding, West of Scotland Branch. "Some Welding Techniques for X-Ray Soundness," by M. R. Kilgour. 39, Elmbank Crescent, Glasgow, C.2.

Institution of Plant Engineers, Kent Branch. "Some Applications of Plastics in Industry," by Dr. C. L. Child. Kings Head Hotel, High Street, Rochester. 7 p.m.

Manchester Metallurgical Society. "Metallurgical Background of Casting Production," by A. Cibula. Manchester Room of the Central Library, Manchester. 6.30 p.m.

Society of Chemical Industry, Corrosion Group. "Economic Aspects of Corrosion," by A. Keynes. 14, Belgrave Square, London, S.W.1. 6.30 p.m.

19th March

Institution of Engineering Inspection, North Western Section. "Surface Finish," by R. C. Spragg. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institution of Production Engineers, Glasgow Section. "Recent Developments in Sintered Oxide Cutting Tools," by R. N. Cook, 39, Elmbank Crescent, Glasgow, C.2.

Southampton Metallurgical Society. "Vacuum Melting of Steel," by J. W. S. Stafford. Small Physics Lecture Theatre, The University, Southampton. 7.15 p.m.

23rd March

North East Coast Institution of Engineers and Shipbuilders. "The Thermal and Elastic Properties of Eight Cast Irons," by Dr. D. Fitzgeorge and Professor J. A. Pope; "An Investigation into the Creep Properties of Two Cast Irons," by C. Wheatley and Professor J. A. Pope. Literary and Philosophical Society's Lecture Theatre, Newcastle upon Tyne. 6.15 p.m.

26th March

Institute of Metals, Sheffield Local Section. "The Nimonic Alloys," by Dr. W. Betteridge. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7.30 p.m.

Institution of Plant Engineers, Sheffield Branch. "Refractories," by T. R. Lynam, Grand Hotel, Sheffield. 7.30 p.m.

31st March

Sheffield Metallurgical Association. "Titanium Production and Properties," by J. W. S. Stafford. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

1st April

Institute of Welding, Manchester and District Branch. Annual General Meeting and Film Show. Reynolds Hall, Manchester College of Science and Technology, Sackville Street, Manchester, 1. 7.15 p.m.

2nd April

Leeds Metallurgical Society. "Special Steel Manufacture," by D. Hall. Low Moor Alloy Steel Co., Ltd., Bradford. 7.15 p.m. The Meeting includes a visit to the Works.

3rd April

Institute of Fuel, South Wales Section. "Industrial Electric Furnaces," by J. C. Harris. Port Talbot. 6 p.m.

7th April

East Midlands Metallurgical Society. "Metallurgical Examination of Failures," by G. A. Cottell. Electricity Lecture Theatre, Carrington Street, Nottingham. 7.30 p.m.

Institute of Metals, Oxford Local Section. Annual General Meeting, followed by a Colloquium on Modern Joining Techniques: (a) Electron Bombardment; (b) Ultrasonic Applications; (c) Non-Metallic Bonding. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

8th April

Society of Chemical Industry, Corrosion Group. Spring Lecture. 14, Belgrave Square, London, S.W.1. 6.30 p.m.

9th April

Liverpool Metallurgical Society. "Boron in Steel," by F. B. Pickering, and 11th A.G.M. Library of the Department of Metallurgy, The University of Liverpool, 146 Brownlow Hill, Liverpool, 3. 7 p.m.

10th April

West of Scotland Iron and Steel Institute. Open Hearth Furnace Maintenance—A Symposium. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

14th-17th April

Institute of Metals. Spring Meeting. Church House, Great Smith Street, London, S.W.1.

Aluminium and its Alloys in 1958

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., F.I.M.

Chief Metallurgist, The Aluminium Development Association

Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.

(*Continued from page 85 in the February issue*)

Constitution

THE appearance of a second edition of Hansen's[103] "Constitution of Binary Alloys," prepared in collaboration with Anderko, is a very important event. The scholarship contained in this volume of 1,305 pages, with 9,600 literature references, 1,286 systems, and 684 diagrams, almost dazzles the ordinary reader. Binary systems between aluminium and 59 elements are included, and in 45 cases an equilibrium diagram is provided. In all these instances the published evidence is set forth and sifted, and the present state of knowledge represented.

Close[104] has redetermined the aluminium-gallium equilibrium diagram; he points out apologetically that his samples were much smaller than is considered ideal for thermal analysis, because of the high cost of gallium. By metallographic examination of slowly cooled alloys, and of alloys annealed for long periods at 500° C., Raynor and Faulkner[105] have established that in the aluminium-rich aluminium-manganese-copper-nickel alloys the compounds $Ni_4\ Mn_{11}\ Al_{60}$ and $Cu_2\ Mn_3\ Al_{20}$ form a complete series of solid solutions. A section is presented through the equilibrium tetrahedral model at 90% aluminium by weight.

Aluminium-magnesium-silicon-copper alloys studied by Collins[106] include the standard materials H11 and H20. He has related the tensile properties of fully heat treated alloys to equilibrium reactions at the heat-treatment temperatures. The effects of magnesium + silicon and of copper were found to be independent, and alloys in which the strength was mainly attributable to copper were more ductile than those depending on magnesium + silicon.

Properties

The low thermal neutron absorption of aluminium renders it attractive to nuclear engineers, and Bold[107] has written an account of the properties of the metal and some of its alloys, including general data and those particularly important as regards atomic reactors. There are a few statements with which not all aluminium technologists would agree—as, for instance, the recommendation for using aluminium-silicon filler wire in welding aluminium-magnesium alloys—but the tabular matter is a useful summary of available information.

The low temperature properties of aluminium and its alloys have long been known to be good, but the special interest arising from the scheme to transport and store liquid methane has led a number of investigators to undertake research. Thus, Lismer[108] has reported notched tensile tests and Navy tear tests on aluminium-magnesium-silicon alloys and aluminium-magnesium alloys of British and American origin, using plate and extrusions, welded and unwelded, at various temperatures down to − 196° C. He concludes that none of these materials shows any tendency to behave in a brittle manner. Sawkill and James,[109] working with aluminium-magnesium alloy plate, have reached very similar conclusions as a result of tear tests and some impact tests, and so, quite independently, have Tomlinson and Jackson,[110] who include some tests on centrally-notched wide specimens. Durham[111] has concentrated on extruded materials, using flat specimens and specimens cut from extruded tube, both welded and unwelded. He shows that, with aluminium-magnesium and aluminium-magnesium-silicon alloys, tensile strength increases at the low temperature without significant loss in elongation, and that in no instance are cracks more readily formed and propagated at − 195° C. than at room temperature. All these papers contain most interesting photographs of fractures, and the "fissured" type exhibited by some of the aluminium-magnesium alloys at low temperature must certainly have alarmed the investigators until it was shown to be in no way associated with brittle behaviour.

Homogenisation at 565° C. of extrusion billets in aluminium-magnesium-silicon alloy has been investigated by McLaughlin,[112] who demonstrates that the practice results in appreciable improvement in hardness of fully heat treated extrusions. Increase in hardness depended upon time of homogenisation, and induction heating was more efficient in this respect than heating in a muffle furnace. Varley, Day and Sendorek[113] have artificially aged at several temperatures solution treated aluminium-zinc-magnesium alloys based on super purity aluminium, and shown that, although strengths increased steadily with ageing temperature, fractures became increasingly intercrystalline and brittle. By means of some excellent electron micrographs, they establish that this intercrystalline weakness is due to denuded zones adjacent to grain boundaries, upon which prefer-

ential precipitation of intermetallic compounds takes place. The ageing characteristics of alloys in the aluminium-zinc-magnesium system have also been studied by Polmear and Young,[114] with a view to assessing the effects of copper, chromium and manganese in aircraft high-strength alloys. Chromium accelerated the rate of elevated temperature ageing, probably by very small particles of the element, formed during solution treatment, acting as centres for aggregation of solute atoms. No such mechanism was found with manganese, which was thought to have little effect on the ageing process. Williams, Hallwood and Hayden[115] have compared the static and fatigue properties of specimens taken from the centre and near the surface of a large extrusion in aluminium-zinc-magnesium-copper alloy (D.T.D.363), and their view is that the loss of longitudinal strength in the centre could be mitigated by overcoming the mass effect in quenching, as, for instance, by dissipating the steam envelope.

The aluminium–7% magnesium alloy is interesting because it has a stress/endurance fatigue curve which is asymptotic and so comparable with typical curves for steel. Stubbington[116] has shown, however, that while this obtains for as-extruded material, any form of heat treatment causes the curve to revert to the typical non-ferrous configuration. Cold working had a beneficial effect on the fatigue properties of the solution treated alloy, although not raising them to the level obtained with extruded material. Working with the fully heat treated aluminium-copper-magnesium alloy B.S.L65, Frost[117] found the reverse effect, in that static preloading in compression or torsion decreased fatigue strength. Prior fatigue testing was shown to have no effect on subsequent fatigue life of specimens taken from areas remote from the surface of the original material. Wood and Segall[118] have applied successive reversals of plastic strain in torsion to cold-worked pure metals, including aluminium, and shown that after critical strain hardening work-softening follows. This is explained as being due to stress relaxation occurring at concentrations of slip in bands, with the occasional creation of new bands resulting in final equilibrium.

The electron micrographs illustrating Koda and Takeyama's[119] paper on slip in stretched pure aluminium–4% copper alloy are most impressive; the bands are short and bend the platelets of precipitate in their path. Cuff and Grant[120] have published an electron micrograph of the surface of a flat tensile specimen in high purity aluminium, strained 8% at room temperature. This shows an interesting fine network structure, on its chemically polished surface, and evidence of grain boundary sliding and migration. Using single crystals and bicrystals in pure aluminium, Fleischer and Chalmers[121] have investigated size effects associated with a grain boundary in tensile samples. They conclude that the major size effect is due to multiple slip, which may extend on each side of the boundary to a distance of the order of the thickness of the sample, but that this would not in itself predict any grain size effect in multigranular samples. Lytton[122] and his co-workers have established that the creep of single aluminium crystals occurs by three separate processes, characterised by three distinct activation energies, which they have calculated from the effect of small abrupt changes in temperature on the creep rate just before and immediately after the temperature change.

A good deal of interest has attached recently to the use in America of aluminium-silicon-magnesium and aluminium-silicon-copper-magnesium heat treated casting alloys based on aluminium of fairly high purity. By keeping the iron content low, high strength with fair ductility or high ductility with fair strength may be attained by adjustment of heat treatment conditions. These alloys and the strong aluminium casting alloys at present in use in this country have been reviewed by Smith,[123] who makes a plea for further consideration for the aluminium-silicon-magnesium type, to provide an alloy capable of replacing all current high strength general purpose alloys. Aluminium powder metallurgical products are now familiar; Towner[124] has expanded their field of application by additions of fairly large amounts of alloying elements such as iron. For example, extrusions from powder compacts of an alloy containing 8% iron and small proportions of chromium, titanium, vanadium and zirconium had outstanding properties in the temperature range 200°–425° C.

The Aluminium Development Association sponsors an extensive programme of structural engineering research at various universities, and Rockey[125, 126] has reported further results on web buckling and web plate design, and on plate girder design. These accounts are available as research reports published by the Association.

Corrosion and Protection

The insubstantial pageant that man creates so laboriously is destined to dissolve, leaving not a rack behind, and the main agent in this Prosperean dissolution is corrosion. The major weapon in the battle against corrosion of metals is knowledge of its mechanisms and effects, and the accumulation of this continues. Brouillette[127] has reported exposure tests on various metals, including aluminium and certain alloys, in the water of Port Hueneme in California. The rate of pitting attack on the pure metal and binary alloys was somewhat greater than that usually experienced in seawater, although the clad aluminium-copper-magnesium alloy behaved well. Pure aluminium has been exposed in the atmosphere, in seawater and in lake water in the Panama canal zone, along with other pure metals and structural steel, and Forgeson[128] and his collaborators have reported results after eight years' exposure. Their conclusions are that aluminium is extremely resistant to corrosion in all environments studied, except that the depth of pitting in lake water was six times that in seawater, as might, perhaps, have been expected.

Interest in the resistance to corrosion of aluminium by water at high temperature stems from atomic energy applications. Lavigne[129] has investigated the effect of cold-working on the attack of high purity aluminium by liquid distilled water at 100, 150 and 200° C., and found that at all these temperatures large amounts of cold work suppress intergranular attack in favour of general corrosion. Using liquid distilled water at 300° C., Carlsen[130] has compared the behaviour of high purity aluminium alloys containing nickel, iron, nickel with iron, copper and nickel with silicon. The aluminium-nickel alloys were the most resistant, and the aluminium-copper alloys the least; the mode of attack was established by metallographic examination.

Following the rapid failure by corrosion of an aluminium–1¼% manganese alloy component in contact with propylene dichloride, Hamstead, Elder and Canterbury[131] made laboratory tests to try to establish the conditions for initiation of attack. They conclude that

the use of aluminium in contact with chlorinated hydrocarbons should not be encouraged until more is known about the limitations of product purity, time, temperature and condition of metal surface in previously successful applications in this field. Marshall and Schafer[132] have tested aluminium-copper-magnesium wrought alloy, solution treated and also air-cooled from the solution treatment temperature, in acid chloride solution, measuring the volume of gas evolved. The solution treated material corroded by pitting, and gas evolution was at a constant rate, while the air-cooled alloy corroded in an integranular manner, and the volume of gas given off increased linearly with time of immersion. It is important to note, however, that the experiments continued only for periods measured in minutes. In testing the effect of metals in solution on the corrosion of other metals in acid and alkaline media, Buck and Leidheiser[133] found that acid attack on aluminium was activated by group VIII elements, and inhibited by group III and IV metals. In alkali the rate of attack was so great that effects were difficult to determine, but beryllium, tin and bismuth provided some inhibition. The corrosion of aluminium by hydrochloric acid was appreciably increased by concentrations of ruthenium and palladium as low as 10^{-8} molar.

The inhibiting effect of hydrofluoric acid on the corrosion of aluminium by fuming nitric acid has been investigated by Mason and Rittenhouse,[134] who find that the protective film formed has the composition $2AlF_3.Al_2O_3$. Increase in the corrosion rate is observed if the HF content rises above 0·4%, and best inhibition is obtained if the concentration is kept near that value. Sundararajan and Char[135] have compared the efficiency of a number of substances as inhibitors of the corrosion of aluminium by dilute solutions of caustic soda ; in no case was the degree of inhibition such as to encourage practical application. The sample of sheet metal used is stated to contain 4% iron and 4% other impurities : there seem some grounds for suspecting migration of decimal points. The laboratory testing of inhibitors for diesel engine cooling systems is complicated by the large number of different metals used, and the difficulty of arriving at a suitable accelerated test. Two types of test were used by Bregman and Boies[136] to compare various inhibitors, a flask type test and a recirculating test incorporating a heat transfer surface. They conclude that for mixed systems, including aluminium, a boron-nitrite type of inhibitor may be developed which is satisfactory.

Rowe[137] introduces his brief note on an instance of corrosion with an aluminium water outlet manifold by calling attention to the excellent service obtained from aluminium and its alloys as materials for motor coach construction. His particular problem was shown to arise from contact with cast iron, and is now avoided either by using soluble oil inhibitor in the coolant or by changing to an aluminium alloy cylinder head. Gases from sour crude oils produced in the Big Horn Basin in Wyoming are very corrosive towards steel, and tests have therefore been made by Brooks[138] of aluminium-magnesium alloy, and a similar alloy clad with aluminium-zinc, in the venting systems of storage tanks. Both materials were unaffected after three years' exposure, which confirms the satisfactory performance of aluminium tank decks in the same area. Cement concrete when wet is alkaline, and can cause some attack on aluminium alloys. Nevertheless a 7 cu. yd. mobile concrete mixer[139] in aluminium-magnesium alloy is giving very good service, and on examination after three years it was found that only about 0·025 in. in thickness had been removed from the shell by corrosion and abrasion.

Vance[140] has corroded strain-aged wires of aluminium–2¼% magnesium and aluminium–3½% magnesium alloys in buffered 3% sodium chloride solution, and concluded that the former is free from stress-corrosion susceptibility, while the latter shows some tendency to this form of failure. This is, of course, contrary to practical experience, where both these alloys are considered safe from this type of attack.

In an article on the barrel finishing of aluminium alloys, Reynolds[141] states that castings are "etched in an acid bath to remove alloying materials from the skin without attacking the aluminium. In this way the castings are left with a skin of near pure aluminium which is easily burnished and is highly weather resistant." This seems an excellent method for producing a clad casting, but the selective etching described would appear extremely difficult of attainment, particularly for alloying elements in solution, or indeed for any of them. Tomkins[142] has described the theory and practice of electropolishing and given as one example of its use the brightening of aluminium car trim. One particular chemical polishing process for aluminium has been discussed by Bates and Coppard,[143] who gave many instances of its application to metal of various purities, and also to alloys.

Brace and Pocock[144] have summarised current methods for the testing of anodic coatings on aluminium, and stated that suitable acceptance tests should indicate the thickness of film, check the efficiency of sealing, and determine corrosion and abrasion resistance. The anodising of aluminium-copper alloys presents special difficulties, and Hérenguel and Lelong[145] have shown that where the copper is out of solution some local attack is inevitable. In solid solution, however, the copper hinders the mechanism of anodic oxidation, and so slows down the process. The use of brightened and anodised aluminium for motor-car radiator grilles, insignias, hub caps, window frames, head lamp surrounds and so forth is extending, and examples have been described and illustrated,[146] with some reference to the technique necessary to attain acceptable finishes.

Over the past few years architectural applications of aluminium have expanded considerably. An account has appeared of good service by aluminium windows,[147] together with details of suitable coating thicknesses and light-fast dyes for anodised frames, and precautions to be taken when contact with other building materials is involved. Following the holding by the Aluminium Development Association of a special meeting with architects, together with a small exhibition at the London Building Centre, an article was published[148] summarising the subjects discussed, which were all concerned with the methods of ensuring durable and light-fast anodic coatings for architectural use. The Association's recommendations for such coatings are set forth in a reprinted paper[149] and an architect's data sheet,[150] while a special folder[151] reproduces the colours of named dyes which are known to be light-fast in outdoor exposure, and may be applied both to aluminium and to the aluminium–5% silicon alloy.

Another use of anodising on aluminium is to provide an abrasion-resistant surface ; this variant of the pro-

cess is usually termed hard anodising. Hard coatings on various alloys, principally of aircraft type, have been subjected to corrosion and abrasion tests and also to stress-rupture tests at elevated temperatures.[152] The anodised specimens gave very similar results to uncoated specimens in this last test, at a temperature of 230° C. Trankla[153] has reviewed recent developments in hard anodising, and described some of its uses in the electronics industry. Hard anodised chassis provide high electrical resistance, good dielectric strength and heat sink properties, while the treatment is also being applied to wire, clips, mounting angles and potting units.

Hamlet's warning to his lady that paint even an inch thick could not protect her from mortality was no doubt true, but nevertheless paint is of great value, both in protecting metals and in improving their appearance. It must be applied, for best results, on a surface correctly prepared, and one method of doing this for aluminium has been described,[154] involving a chromate conversion coating. After the pretreatment, the right primer. Rigg and Skerrey[155] have now completed 10 years' exposure with their comparative tests of priming paints for aluminium, and their results fully confirm those that they published after three and a half years. All the top coats used were aluminium paint, and the exposures were rural, industrial and marine. Zinc chromate and zinc tetroxychromate were the best primers, while iron oxide was close behind, but red lead was unsatisfactory. In this connection, some of the results reported by Greenblatt[156] are particularly interesting; he found that the potentials in seawater of aluminium and other metal rods coated with various paints were the same as those of the bare metals, but with vinyl red lead primer the painted aluminium specimens eventually became markedly negative to bare aluminium. He suggests that this may be due to some electrochemical reaction involving the red lead pigment.

The insides of cast aluminium alloy beer barrels[157] are treated by an acid conversion coating and sprayed with an epoxy resin, which is cured by stoving, to provide a highly protective layer. Although a good deal of experimental work on vitreous enamels for aluminium was done in this country about a decade ago, no industrial applications followed at that time. The last year or so has seen a considerable recrudescence of interest, and frits are now available; methods of applying them and the types of service for which they are suitable have been described.[158]

Hill[159] has surveyed the methods of manufacture of aluminium powder and paste and their principal applications. He considers the outstanding feature of aluminium powder to be its versatility, and proceeds to establish this fact by noting that it is used in the production of aerated concrete, priming paints, finishing paints and sintered aluminium powder products. To this list could also be added pyrotechnics, inks, incorporation in plastics and, no doubt, other uses.

Aluminium is extensively used for the protection against corrosion of steelwork, being applied by metal spraying. The largest single contracting works specialising in sprayed coatings is Metallisation, Ltd., at Dudley, and the plant has been described by Mansford.[160] Accelerated tests to assess the value of protective systems in the Sydney atmosphere have been carried out by Bright,[161] who reaches the most encouraging conclusion that for salt atmospheres sprayed aluminium coatings have long life, and are considerably more durable than those of zinc. Mansford[162] has discussed sprayed and diffused metal coatings as protection for steel against elevated temperatures, and he points out that when aluminising is used for this purpose, it is most important that zinc be absent. Thus if the part to be treated has previously been galvanised, the aluminised surface will be spoiled by an eruption of nodules.

The vacuum deposition of aluminium is used principally for decorative finishes on jewellery and other novelties, and for the production of mirrors. Remond and Johnson[163] have described the process, stressing the importance of good finish on the article to be coated, since this determines the quality of the final finish.

Applications

By referring to the levels of consumption of aluminium before and after each of the two world wars, Swabey[164] shows that when users become accustomed to working with aluminium they continue to demand it. He reviews present applications of the metal and its alloys, and gives the answers to problems encountered by those more experienced in working with other metals. Nock and Keller[165] have reviewed new applications for various metals including wrought aluminium alloys.

Buildings and structures, and various parts for them, continue to be a major application of aluminium and its alloys. Craggs[166] has described recent structural developments in Belgium, including warehouses, air terminal buildings and pavilions at the Brussels Exhibition. In Holland, a 100 foot mobile tower[167] has been made in wrought and cast aluminium alloy (equivalent to HV30 WP and LM10-W) for use in the cleaning and renovation of cathedrals; despite its size, it may be dismantled by eight men in four hours, and transported in one pantechnicon. In this country a 300 foot static tower[168] includes in its construction 50 tons of material, of which 40 tons are wrought aluminium alloy (H30 WP); it is designed to withstand a wind speed of 80 knots. Continuing with the tall and graceful, reference must be made to the new church at Adeyfield, Herts, which has an aluminium-clad spire,[169] projecting through a central skylight both into the church below and the sky above.

A tubular conveyor bridge[170] in aluminium alloy has been erected at Breslau in Ontario, fabrication being by welding in an alloy equivalent to H20 WP, with aluminium–5% magnesium welding wire; the single span is 180 ft. long. In order to reduce maintenance in inevitably humid conditions, the building housing the new ship model testing tank[171] for the National Physical Laboratory at Feltham is largely constructed in aluminium. It is over ¼ mile long, and another use of aluminium is in the lightning protection. The sheeting of large prefabricated hangar doors[172] for B.O.A.C. at London Airport is in aluminium alloy (N3) corrugated sheet, fastened to a steel framework by hollow rivets. Burke[173] has described the new stand for the Rugby football ground at Cardiff Arms Park; the roof covering is troughed decking in aluminium alloy, secured to purlins by clips.

Applications Brochure No. 12 of the Aluminium Development Association describes the types of aluminium[174] window available, materials and methods of manufacture, and correct installation practices. It is well illustrated, and includes a number of pictures in colour. Aluminium windows have been used in Lloyd's new building[175] in London, and much aluminium is also incorporated in interior decorative fittings. Spescha[176]

has given a detailed account of the design and installation of aluminium balustrades in Switzerland; costs have been reduced by the use of standardised components. Handrails[177] for more work-a-day purposes such as sewage plant, chemical works and shipbuilding are now available in this country, the stanchions being forged and the tubing extruded, both in alloy H30. Ease of installation of aluminium sandwich walls[178] has been improved in the U.S.A. by the use of studs welded to the building structure; on these studs are impaled the aluminium inner skin, the insulation material, and the aluminium outer cladding.

To prevent the discolouration by water seepage of the roofs of escalator shafts in the London Underground, false ceilings[179] of aluminium sheet, anodised silver finish, have been constructed; water will run from them into concealed gutters on either side. The Aluminium Development Association has issued an applications brochure on aluminium rainwater goods,[180] which covers cast and extruded types as well as those made by forming from sheet.

Two very large tanks[181] have been made by welding in aluminium-magnesium alloy to contain fresh drinking water on board oil tankers, and such tanks may become standard in future vessels. Complete sets of welded aluminium McGregor insulated tween-deck hatch covers (*sic*) have been installed in three Royal Mail Line passenger vessels.[18] Aluminium alloy has proved to be an excellent material for ships' masts,[183] and examples have been given of methods of construction.

A recently built diesel trawler has a welded aluminium wheelhouse,[184] attached to the steel deckhouse by riveting. Extensive use has been made of aluminium alloy in a combined bauxite and oil carrier[185] built in Japan; superstructure, hatch cover, funnel, and many other details were made in aluminium-magnesium alloy by welding and riveting.

The increasing interest in welded construction for small craft in aluminium alloy has been shown by accounts of vessels recently launched. Thus *Dark Scout* was the first all-aluminium welded ship[186] in the Royal Navy; this fast patrol boat, over 70 ft. long, was built using the consumable electrode method of welding. The first aluminium vessel[182] to be certified by the American Bureau of Shipping was the *Sumter*, an all-welded tugboat made in aluminium-magnesium alloy. Its name might be significant; perhaps it was chosen as a harbinger of civil war between aluminium and steel in small boat construction. Also made in America was a 58 ft. all-welded aluminium-alloy yawl[188], with a mast 72 ft. tall to carry a sail area of 1,604 sq. ft. The interior is finished in English oak; there is no mention in the account of jolly tars amongst the crew.

Leaving welding for more traditional riveted construction, two 60 ft. ramped cargo lighters[189] have been built in aluminium alloy in this country for the Royal Pakistan Navy, with mean light draught of only 1 ft. A cutter[190] for Trinity House Thames pilots, 32 ft. long, has a hull of 10 s.w.g. sheet, fixed to stringers and frames, all in aluminium-magnesium alloy N5. It is well-known that the record-breaking craft, *Bluebird*, is of aluminium alloy, and information has been published regarding the thermal insulation[191] of the jet pipe; this consists of several layers of aluminium foil, flat, corrugated and crimped.

Slow but steady progress is being made in the railway applications of aluminium and its alloys. Twelve prototypes have been ordered of a new design of tube car for the London Central Line,[192] and after trials approximately 330 more cars will be required. They will have a natural coloured aluminium exterior. Bolton[193] has reviewed the use of aluminium in private motor-cars, and he concludes that at present it is limited to those fields in which an obvious saving is made in first costs. One of the oldest companies[194] manufacturing commercial vehicles in aluminium alloy recently held an open day, and an account has been presented of its activities from 1919 to the present day. A new design of road tanker[195] in aluminium alloy incorporates a three-point flexible suspension system with a four-section tank built up by welding. Aluminium foil has a number of applications in road engineering;[196] the reflectors in cat's eyes, traffic line markings, and now as an overlay for concrete expansion joints to prevent cracking of bituminous top surfaces. The parking meters[197] recently installed in Mayfair to the delight of some and the despair of others are housed in enamel finished pressure die castings in aluminium alloy LM2-M.

A part of the Exhibition held in conjunction with the Aluminium Development Association's Symposium on Aluminium in Packaging held in June 1958.

Packaging applications of aluminium account for something of the order of 10% of the semi-fabricated products made in this country, and the symposium on aluminium in packaging held in June, 1958 by the Aluminium Development Association therefore attracted considerable attention both here and oversea. A book[198] has now been published, incorporating the eight papers that were presented, covering all aspects of the subject, and the lively discussion which took place. Elliott[199] has provided an account of aluminium in packaging from the point of view of design, forming one of a series of articles on the subject devoted to different materials. In Hawaii there is now in operation what is claimed to be the most automatic beverage canning line in the world,[200] which impact extrudes, lacquers, fills, seals and pasteurises aluminium beer cans, and packs them in cartons ready for delivery.

The above references are to throw-away packages in aluminium, but progress has also been made with returnable items. Retemba containers[201] are made from aluminium alloy sections for framing and laminated timber

Air Marshal Sir R. Owen Jones, K.B.E., C.B., A.F.C., R.A.F. (Retd.), M.I.Mech.E., President of the Institution of Mechanical Engineers, opening on 28th October, 1958, the Symposium on Aluminium Pressure Vessels arranged by the Institution, the Aluminium Development Association, and other technical bodies.

panels, and are collapsible to permit ease of return when empty. Large standard-size containers, entirely of aluminium alloy, are used in the Tote system[202] of bulk materials handling, and the application of this system to the transport of fine chemicals has been described. Even larger containers, suitable for transport by road, rail or sea have been designed and built, in this country and abroad, and one of 500 cu. ft. capacity has been described[203] and illustrated.

Cabinets for radar equipment,[204] mainly in aluminium alloy, are made by welding and each involves some 3,000 separate parts. A famous refrigerator manufacturer[205] uses aluminium liners for his larger models, and evaporator trays are produced from aluminium pipe and embossed sheet by brazing. An "Iron Lung" has been designed and made[206] entirely in aluminium, if the contradiction in terms may be permitted. One of the best-known domestic steam irons has a cast aluminium alloy sole-plate and its water-tank[207] is fabricated from pure aluminium sheet by tungsten-arc welding. American methods of manufacture of costume jewellery in aluminium and its alloys have been reviewed by Atkinson.[208] The McArthur miniature microscope[209] truly lives up to its epithet; it is based on a block of aluminium alloy, $4 \times 2\frac{1}{2} \times 2$ in., and weighs only 18 oz.

The caustic comments of architects, artists and even octagenarian actors have called attention to the lack of public satisfaction with modern street lighting columns and a new material trying to improve matters is aluminium.[210] Welding cables in aluminium have the advantages of lightness, cooler operation, ease of handling and low cost; Stone[211] has described recent development in this field. The Americans have used foil mulches[212] in horticulture for a considerable time, and now special rolls of hard foil, 6 in. wide and 50 ft. long, are available to the gardener in this country. Bailey[213] has surveyed the uses of aluminium in the dairy industry, and his paper forms a useful summary of suitable alloys, recent developments in fabrication, and correct cleaning procedures. It is available as an A.D.A. reprint.

Keen interest in the design, manufacture and use of aluminium pressure vessels led to a very large attendance at a symposium on the subject organised by the Institution of Mechanical Engineers, the Aluminium Development Association, and other technical bodies. The papers read and the discussion, both verbal and written, will be published by the Institution early in 1959.

Standards

In 1958 the triennial general assembly of the International Standards Organisation was held in Harrogate, and was accompanied by many technical meetings, including one of the committee dealing with light metals and their alloys. Good progress was made, and it is expected that the first international recommendations on this subject will be published fairly soon.

Turning to national activities, a very useful step has been the re-issue of the British Standard dealing with anodised aluminium,[214] fully revised and brought in line with modern thinking, particularly as regards film thicknesses. Another revised standard is that on aluminium rainwater goods,[215] which replaces the two previous separate standards on this subject, and now covers all types. Recommendations for manual tungsten-arc welding of light alloys[216] have been issued as a British Standard, covering joint preparation, filler materials, shielding gas, welding procedure and testing and inspection. This standard has been reviewed in a journal article.[217].

In the framework of the aluminium-zinc-magnesium-copper series of high strength wrought alloys are many variants, and even within previous standard compositions different alloys were made. This has now been recognised by the issue of several D.T.D. specifications[218] distinguishing principally between differing contents of manganese and chromium, and covering plate, forgings, and bars, and extruded sections. D.T.D. 746 has been revised[219] to bring it into line with the modern composition of the aluminium-copper-magnesium heat treated aircraft alloys. Other Ministry of Supply specifications are concerned with forgings in aluminium-copper-magnesium-nickel-iron alloy[220] (D.T.D. 5084), and the chem-milling of sheet and plate[221] (D.T.D. 932).

The closing days of 1958 were marked by the issue of an important statement from an authoritative source! Beachcomber[222] has reported details of a nibbling machine which will cut duralumin (significance of term obviously not fully realised) and which, he finds, may be used in addition to its stated purposes of "peening, swaging, joggling, louvre-cutting, flanging and slotting," for "dooping, narving, morgling, foping, buffing, and even tradging." Note will be taken of this development in metal-working circles, and no doubt further technical articles on the subject may be expected; or so, at any rate it is hoped, by at least one student of such matters.

REFERENCES

The Aluminium Development Association maintains extensive Library facilities, and is prepared to lend its accessions for short periods to bona-fide enquirers in this country.

103 Hansen, M., and Anderko, K., "Constitution of Binary Alloys," McGraw-Hill Book Company, 1958, pp. 1,305.
104 Clare, J. W. H., "Note on a Redetermination of the Aluminium-Gallium Equilibrium Diagram," *J. Inst. Metals*, 1958, **86**, 431–432.
105 Raynor, G. V., and Faulkner, C. R., "A Note on Aluminium-Rich Aluminium-Manganese-Copper-Nickel Alloys," *ibid.*, 323–324.
106 Collins, D. L. W., "Constitutional Factors Affecting the Tensile Properties of Wrought Aluminium-Magnesium-Silicon-Copper Alloys," *ibid.*, 325–336.
107 Bold, J. M., "Aluminium and Its Alloys," *Nuclear Engineering*, 1958, **3**, 296–302.
108 Lismer, R. E., "Low Temperature Properties of Aluminium-Magnesium Alloys," *British Welding Journal*, 1958, **5**, 523–538.
109 Sawkill, J., and James, D., "Tear Tests on Aluminium-Magnesium Alloy Plate," *ibid.*, 517–522.
110 Tomlinson, J. E., and Jackson, D. R., "Low Temperature Properties of Welded and Unwelded Al–5% Mg Alloy Plates," *ibid.*, 499–510.
111 Durham, R. J., "Extruded Aluminium Alloys for Low Temperature Service," *ibid.*, 510–516.
112 McLaughlin, J. K., "Heat Treating Affects Aluminum Extrusions," *Metal Progress*, 1958, **74** (1), 105–107.
113 Varley, P. C., Day, M. K. B., and Sendorek, A., "The Structure and Mechanical Properties of High-Purity Aluminium-Zinc-Magnesium Alloys," *J. Inst. Metals*, 1958, **86**, 337–351.
114 Polmear, I. J., and Young, P. S., "The Ageing Characteristics of Two Commercial Alloys Based on the Aluminium-Zinc-Magnesium System," *ibid.*, **87**, 65–70.
115 Williams, T. R. G., Hallwood, S. W., and Hayden, R. W., "Properties of a Large Extrusion Supplied to Specification D.T.D.363," *Metallurgia*, 1958, **58**, 219–224.
116 Stubbington, C. A., "Some Observations on the Fatigue Behaviour of Aluminium–7% Magnesium Under Various Conditions of Heat-Treatment," *ibid.*, 165–171.
117 Frost, N. E., "The Fatigue Strength of Specimens Cut from Pre-Loaded Blanks," *ibid.*, **57**, 279–282.
118 Wood, W. A., and Segall, B. L., "Softening of Cold-Worked Metal by Alternating Strain," *J. Inst. Metals*, 1958, **86**, 225–228.
119 Koda, S., and Takeyama, T., "Interaction Between Slip Bands and Particles of Precipitate in an Aluminium Alloy," *ibid.*, 277–280.
120 Cuff, F. B., and Grant, N. J., "Grain-Boundary Sliding and Migration in High-Purity Aluminum at Room Temperature," *A.I.M.E. Trans.*, 1958, **212**, 355–356.
121 Fleischer, R. L., and Chalmers, B., "Size Effects in the Deformation of Aluminum," *ibid.*, 265–274.
122 Lytton, J. L., Shepard, L. A., and Dorn, J. E., "The Activation Energies for Creep of Single Aluminum Crystals Favourably Oriented for (111) (101) Slip," *ibid.*, 220–225.
123 Smith, F. H., "Stronger Aluminium Casting Alloys," *Metallurgia*, 1958, **57**, 64–70.
124 Towner, R. J., "Atomized Powder Alloys of Aluminum," *Metal Progress*, 1958, **73** (5), 70–76.
125 Rockey, K. C., "Web Buckling and the Design of Webplates," 1958, Research Report No. 36 of the Aluminium Development Association.
126 Rockey, K. C., "Plate Girder Design," 1958, Research Report No. 37 of the Aluminium Development Association.
127 Brouillette, C. V., "Corrosion Rates in Port Hueneme Harbor," *Corrosion*, 1958, **14**, 352t–356t.
128 Forgeson, B. W., Southwell, C. R., Alexander, A. L., Mundt, H. W., and Thompson, O. J., "Corrosion of Metals in Tropical Environments," *ibid.*, 73t–81t.
129 Lavigne, M. J., "Effects of Cold Working on Corrosion of High Purity Aluminum in Water at High Temperatures," *ibid.*, 226t–228t.
130 Carlsen, K. M., "Structural Features of Corrosion of Aluminum Alloys in Water at 300° C.," *ibid.*, 53t–56t.
131 Hamstead, A. C., Elder, G. B., and Canterbury, J. C., "Reaction of Certain Chlorinated Hydrocarbons with Aluminum," *ibid.*, 189t–190t.
132 Marshall, T., and Schafer, G. J., "Hydrogen Evolution from Duralumin Exposed to Acid Salt Solution," *J. Applied Chem.*, 1958, **8**, 303–310.
133 Buck, W. R., and Leidheiser, H., "The Activation and Inhibition of Corrosion of Metals by Metallic Cations," *Corrosion*, 1958, **14**, 308t–312t.
134 Mason, D. M. and Rittenhouse, J. B., "Mechanism of Inhibiting Effect of Hydrofluoric Acid in Fuming Nitric Acid on Liquid-Phase Corrosion of Aluminum and Steel Alloys," *ibid.*, 345t–347t.
135 Sundararajan, J., and Char, T. L. R., "Inhibition of the Corrosion of Aluminium in Alkaline Solutions," *Corrosion Prevention and Control*, 1958, **5** (5), 55–56.
136 Bregman, J. L., and Boies, D. B., "Laboratory Testing of Railroad Diesel Cooling System Corrosion Inhibitors," *Corrosion*, 1958, **14**, 275t–279t.
137 Rowe, L. C., "The Motor Coach and Aluminum," *ibid.*, 163t–164t.
138 Brooks, R. E., "Elimination of a Tank Vent Line Corrosion Problem through the Use of Aluminum Pipe and Fittings," *ibid.*, 495t.
139 Anon., "Concrete Mixer—a Service Report," *Light Metals*, 1958, **21**, 250.
140 Vance, W. J., "The Relationship Between Magnesium Content and Stress-Corrosion Susceptibility of Aluminium-Magnesium Alloys," *J. Applied Chem.*, 1958, **8**, 18–23.
141 Reynolds, E. A., "Precision Barrel Finishing of Aluminium Alloy Castings," *Industrial Finishing*, 1958, **10** (118), 24–25.
142 Tomkins, A. A., "Electropolishing and Related Techniques," *Metal Finishing Journal*, 1958, **4**, 305–312, 316.
143 Bates, W. K., and Coppard, C. D., "Polishing Aluminium and Its Alloys," *ibid.*, 5–10, 26.
144 Brace, A. W., and Pocock, K., "Methods of Testing Anodic Coatings on Aluminium," *Industrial Finishing*, 1958, **10** (119), 33–34.
145 Hérenguel, J., and Lelong, P., "Some Comments on the Anodic Oxidation of Aluminium Alloys Containing Copper," *Metal Finishing Journal*, 1958, **4**, 20–23.
146 Anon., "Motor Industry Extends Use of Anodised Aluminium Trim," *Industrial Finishing*, 1958, **10** (123), 30–33.
147 Anon., "Window Frames in Aluminium Give Good Service," *ibid.*, **10** (125), 36–37.
148 Anon., "Architectural Anodising," *Light Metals*, 1958, **21**, 328–329.
149 Anon., "Architectural Anodised Aluminium," The Aluminium Development Association, 1958, Reprint No. RP74, pp. 4.
150 "Colour Anodising of Aluminium for Exterior Work," Architect's Journal Library of Information Sheets 675, 1958, compiled from information supplied by the Aluminium Development Association.
151 "Colour Chart for Light-Fast Weather Resistant Anodised Aluminium," The Aluminium Development Association, 1958.
152 Anon., "Hard Oxide Coatings on Aluminium Investigated," *Industrial Finishing*, 1958, **10** (121), 36–37.
153 Trankla, J. E., "Developments in Hard Anodising of Aluminium," *Light Metals*, 1958, **21**, 218–219.
154 Anon., "Finishing Aluminium Alloy Fan Castings," *Metallurgia*, 1958, **57**, 29–30.
155 Rigg, J. G., and Skerrey, E. W., "Priming Paints for Light Alloys," *J. Inst. Metals*, 1958, **86**, 421–424.
156 Greenblatt, J. H., "Note on the Characteristics of Potential-Time Curves for Painted Non-Ferrous Metals," *J. Applied Chem.*, 1958, **8**, 229–232.
157 Anon., "Aluminium Beer Cans Given Epikote Lining," *Industrial Finishing*, 1958, **10** (125), 35.
158 Anon., "Enamels for Aluminium Now Available in Britain," *ibid.*, **10** (122), 22–24, 55.
159 Hill, V. J., "The Production and Uses of Aluminium Powder and Paste," *Metallurgia*, 1958, **57**, 75–78.
160 Mansford, R. E., "Metallisation, Ltd.," *Metal Industry*, 1958, **93**, 296–298.
161 Bright, H. E., "The Protection of Steel Structures in Salt Atmospheres," *Corrosion Technology*, 1958, **5**, 17–20.
162 Mansford, R. E., "Sprayed and Diffused Metal Coatings," *Metal Industry*, 1958, **93**, 413–416.
163 Remond, G. B., and Johnson, A. R., "Vacuum Depositions of Metals," *Metal Finishing Journal*, 1958, **4**, 393–397.
164 Swabey, P. S. W., "The Advantages and Problems of Using Aluminium," *Sheet Metal Industries*, 1958, **35**, 685–692, 698.
165 Nock, J. A., and Keller, F., "What's New in Everyday Uses for Metals: Aluminum-Wrought Alloys," *Metal Progress*, 1958, **74** (4), 114–116.
166 Craggs, H. R., "Recent Structural Aluminium Developments in Belgium," *Light Metals*, 1958, **21**, 213–218, 248–250.
167 Anon., "Hundred-Foot Tower on Wheels," *ibid.*, 319.
168 Anon., "Three-Hundred-Foot Tower in Aluminium," *ibid.*, **291**.
169 Anon., "New Church has Aluminium Spire," *Metal Finishing Journal*, 1958, **4**, 104.
170 Anon., "Welded Tubular Conveyor Bridge," *Light Metals*, 1958, **21**, 96–97.
171 Anon., "Ship Model Tank at Feltham," *Shipping World*, 1958, **139**, 382–384.
172 Anon., "Fabricated Hangar Doors," *Welding and Met. Fab.*, 1958, **26**, 53–55.
173 Burke, J. M., "The South Stand at Cardiff Arms Park," *British Welding Journal*, 1958, **5**, 2–9.
174 "Aluminium Windows," The Aluminium Development Association Applications Brochure No. 12, 1958, pp. 59.
175 Anon., "Aluminium at Lloyd's," *Metal Industry*, 1958, **93**, 259–260.
176 Spescha, M., "Standardized Balustrades for Architectural Applications," *Light Metals*, 1958, **21**, 90–93.
177 Anon., "Aluminium Handrails," *Metallurgia*, 1958, **58**, 184.
178 Anon., "Welded Studs Facilitate Fabrication of Field-Assembled Insulated Aluminum Sandwich," *Welding Journal*, 1958, **37**, 141–142.
179 Anon., "False Ceilings," *Metal Industry*, 1958, **92**, 259.
180 "Aluminium Rainwater Goods," The Aluminium Development Association, 1958, pp. 44.
181 Anon., "Light Alloy Water Tanks for Tankers," *Metallurgia*, 1958, **57**, 311.
182 Anon., "Aluminium Hatch Covers," *Shipping World*, 1958, **139**, 203.
183 Anon., "Aluminium in Marine Construction," *Light Metals*, 1958, **21**, 78–79.
184 Du Cane, R., "An All-Welded Trawler," *Welding and Met. Fab.*, 1958, **26**, 216–221.
185 Anon., "Light Alloys in Ore/Oil Carriers," *Shipping World*, 1958, **138**, 272–273.
186 Anon., "H.M.S. 'Dark Scout,'" *Light Metals*, 1958, **21**, 135.
187 Anon., "First Aluminum Tugboat Features All-Welded Construction," *Welding Journal*, 1958, **37**, 803–804.
188 Anon., "All-Welded Aluminum Alloy Yawl," *ibid.*, 142.
189 Anon., "Aluminium Cargo Lighters," *Metal Industry*, 1958, **93**, 360.
190 Anon., "Light Alloy Pilot's Cutter," *Shipping World*, 1958, **138**, 11–12.
191 Millar, M. L., "Thermal Insulation on Bluebird's Power Unit," *Light Metals*, 1958, **21**, 31.
192 Anon., "Prototype Cars for L.T.E. Central Line," *Railway Gazette*, 1958, **109**, 450.
193 Bolton, R. K., "The Use of Aluminium and Its Alloys in Private Cars," *Metallurgia*, 1958, **57**, 59–63.
194 Anon., "Commercial Vehicles Old and New," *Light Metals*, 1958, **21**, 318.
195 Anon., "Road Tankers in Aluminium," *ibid.*, 184–185.
196 Anon., "Aluminium Foil on the Road," *ibid.*, 80.
197 Anon., "Parking Meters," *ibid.*, 204.
198 "Aluminium in Packaging," The Aluminium Development Association, 1958, pp. 183.
199 Elliott, E., "The Art of Packaging: the Properties of Aluminium," *Art and Industry*, 1958, **65** (385), 10–17.

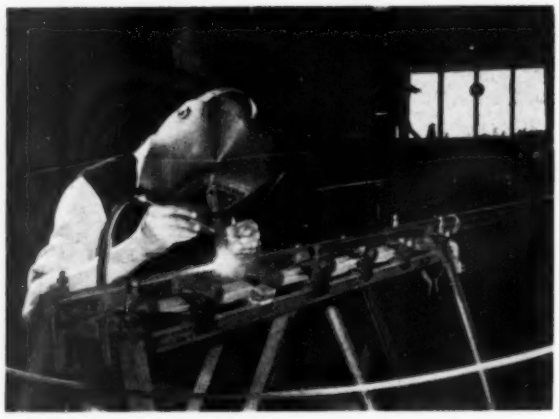
200 Anon., "First Aluminium-Canned Beer," *Modern Packaging*, 1958, **32** (1), 106–110, 228.
201 Anon., "Collapsible Container of Wood and Metal," *Light Metals*, 1958, **21**, 110.
202 Anon., "Aluminium Facilitates the Handling of Fine Chemicals," *ibid.*, 311–312.
203 Anon., "Lightweight Containers," *Shipping World*, 1958, **139**, 10.
204 Anon., "Sealed Cabinets for Radar Equipment," *Light Metals*, 1958, **21**, 260–261.
205 Anon., "Works Practice at Lec Refrigeration, Ltd.," *Sheet Metal Industries*, 1958, **35**, 417–427, 471.
206 Anon., "Aluminium Respirator Cabinets," *Light Metals*, 1958, **21**, 357–359.
207 Anon., "Aluminium Tank for Steam Iron," *ibid.*, 182–183.
208 Atkinson, R. H., "Materials and Processes in Manufacture of Costume Jewellery," *Metal Progress*, 1958, **73** (3), 74–78.
209 Wambeek, R., "Miniature Microscope," *Metal Treatment*, 1958, **25**, 288–290.
210 Anon., "Light Alloy Street Lamps," *Metal Industry*, 1958, **94**, 299.
211 Stone, J. G., "Aluminium Welding Cable," *Welding Journal*, 1958, **37**, 320–327.
212 Anon., "Aluminium Foil in the Garden," *Light Metals*, 1958, **21**, 54.
213 Bailey, J. C., "Aluminium for the Dairy Industry," *Journal of the Society of Dairy Technology*, 1958, **11**, 50–58.
214 B.S. 1615 : 1958 "Anodized Aluminium."
215 B.S. 2997 : 1958 "Aluminium Rainwater Goods."
216 B.S. 3019 "General Recommendations for Manual Inert-Gas Tungsten-Arc Welding." Part 1 : 1958 "Wrought Aluminium, Aluminium Alloys and Magnesium Alloys."
217 Anon., "Welding Standard for Aluminium and Magnesium," *Light Metals*, 1958, **21**, 363.
218 D.T.D. 5024 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Manganese Alloy Forgings."
D.T.D. 5034 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Chromium Alloy Forgings."
D.T.D. 5044 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Manganese Alloy Bars and Extruded Sections."
D.T.D. 5050A : April, 1958. "Aluminium-Zinc-Magnesium-Copper-Chromium Alloy Plate."
D.T.D. 5054 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Chromium Alloy Bars and Extruded Sections."
D.T.D. 5060A : April, 1958. "Aluminium-Alloy-Coated Aluminium.-Zinc-Magnesium-Copper-Chromium Alloy Plate.
D.T.D. 5064 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Manganese Alloy Bars and Extruded Sections."
D.T.D. 5074 : March, 1958. "Aluminium-Zinc-Magnesium-Copper-Chromium Alloy Bars and Extruded Sections."
219 D.T.D. 746A : July, 1958. "Aluminium-Coated Aluminium-Copper-Magnesium-Silicon-Manganese Alloy Sheets and Strips to Close Tolerances."
220 D.T.D. 5084 ; October, 1958. "Aluminium-Copper-Magnesium-Nickel-Iron Alloy Forgings."
221 D.T.D. 932 : January, 1958. "Chemical Contouring of Aluminium and Aluminium Alloy Sheet and Plate."
222 Beachcomber, "By the Way," *Daily Express*, December 29th, 1958, p. 4.

Welded Metal Masts Featured at Boat Show

ONE of the features of the Fifth National Boat Show, held at Olympia at the beginning of this year, is the increasing use of welded metal masts in small racing craft. These British-made welded metal masts are also being increasingly exported to many countries overseas. In recent years there has been a trend among designers and skippers of small dinghies to improve the racing performance of these craft with masts fabricated from aluminium-magnesium alloy. Wooden masts, apart from their higher liability to breakage and the present problem of finding suitable timber, also absorb water, with a resultant increase in weight.

One of the pioneering manufacturers of welded aluminium-magnesium alloy masts in Britain, Sheet Metal Craft, Ltd., of Tichfield, Hants., fabricates them for well-known British small craft designer Mr. Ian Proctor. They have been exported to twenty-one overseas countries, including the U.S., Canada, Sweden, Holland, South Africa, Southern Rhodesia, New Zealand, India and Australia. Among the latest orders was a shipment of a hundred masts for a fibre glass 16-ft. "Day Sailer" in the U.S. This new type of mast is being fitted to many famous class racing boats, including *The Flying Dutchman* which has been chosen for the next Olympic Games. *The Flying Dutchman* committee has accepted the mast as satisfactory for performance and weight, and about fifty of these masts have so far been supplied to various parts of the world for this class of boat. Other national craft which use similar masts are the Flying 15, National 12, National 14 and Hornet. The principal advantages of the masts manufactured by Sheet Metal Craft are lightness in weight, strength and resistance to corrosion. they also provide a clean lead-in to the mainsail, and are predictable for flexing and bending qualities.

Magnesium-aluminium alloy extruded sections are used for manufacturing the masts. These vary in weight according to the size of the boat for which they are designed. Tapering, to reduce weight aloft, is effected by making a longitudinal cut in the tube, which is then rewelded by the Argonarc process. This process gives deep penetration and minimum distortion, and since no flux is used, the post-weld cleaning problem is eliminated. It has been found to be economical, as twelve complete masts can be welded with one 200 cu. ft. cylinder of argon.



Welding metal masts by Argonarc process

The mast is made watertight with capping of the summit, and a wooden plug is inserted at the base. Near the base, sheaves for halyard outlets or winches are fitted with the aid of Chobert rivets. Above deck level, the track section is opened to facilitate a sliding goose neck for the boom attachment. In some instances, a rectangular alloy section is welded into the mast to provide a housing for the sheave cage of the jib. This allows the jib halyard to pass right through the mast into the sail track. In other instances, at a point near the jib sheave cage, a small semi-circular alloy tube is fitted through the mast, allowing the spinnaker halyard to pass down through the sail track. Both these fittings are welded into place by the Argonarc process.

Pre-Coated Resin Sand

To meet the increased demand for Dohmfrac pre-coated resin sand for shell moulding and shell core production, a third manufacturing plant is now in full production at the Burslem, Stoke-on-Trent works of Mellor Mineral Mills—one of the Dohm Group of Companies. Known as the No. 3 Plant, the new premises now permit large batch production of the material.

Some Preliminary Experiments on the Continuous Compaction of Titanium, Molybdenum and Tungsten

By P. Evans, M.A., Ph.D., and G. C. Smith, M.A.

*University of Cambridge, Department of Metallurgy**

The authors describe the results of a preliminary survey of the possibilities of using continuous compacting methods for metals such as titanium, molybdenum and tungsten powders. The technique adopted consisted of rolling to strip followed by sintering. An argon atmosphere was used for titanium and although strip of reasonable strength was produced, the ductility was low, due to contamination from the atmosphere. The molybdenum and tungsten strip was sintered in vacuo but the green strength was low, probably as a result of the powder being too fine and having an unsatisfactory size distribution. The use of some form of binder and a hydrogen atmosphere is suggested.

A NUMBER of investigations have been made in recent years of the direct rolling of metal powders into sheet and strip.[1-9] The properties of products made in this way can compare very favourably with the properties of cast and forged or rolled material. Most of the published work refers, however, to relatively common metals such as copper, nickel and iron, and in these cases the advantages of using a powder compaction method to produce strip are not immediately obvious. For the higher melting point and the more reactive metals, the method could have considerable advantages. Thus, for the very high melting point metals, normal melting, casting and forging techniques are difficult, if not impossible, and batch powder methods are normally used to produce such metals in bar form, following by working to produce sheet or strip. Direct rolling to strip would avoid a number of intermediate stages. Even where casting and forging methods can be used, if the metal is reactive, considerable contamination may occur, which would not occur with a powder metallurgy technique involving compacting at room temperature and sintering *in vacuo* or in an inert gas. The powder method of producing strip also lends itself readily to variations of composition by incorporation of metallic or even non-metallic additions, the latter in particular often being difficult to achieve in other ways.

The work described in the present paper is a preliminary survey of the possibility of using continuous compacting methods for metals such as titanium, molybdenum and tungsten.

Experimental

Materials

The titanium powder used was prepared by grinding a relatively pure titanium sponge, of Japanese origin, after it had been embrittled by hydrogen : the hydrogen was then removed by desorption. The powder was 80% by weight −100 mesh +300 mesh, and the remaining 20%−300 mesh. The powder particles were irregular in shape, which makes compaction easier. A certain amount of internal porosity was also present. The molybdenum and tungsten† powders were both fine, the mean spherical particle diameters being 10 microns and 6 microns, respectively.

Rolling and Sintering

The powders were rolled in a two-high mill having 8 in. diameter rolls.[7] Prior to rolling, the rolls were screwed into contact so that the initial roll gap was zero, the initial contact pressure between the rolls being considerably greater for the molybdenum and tungsten than for the titanium. The rolling speed for titanium was 4 ft./min. and for molybdenum and tungsten 2 ft./min.

The sintering of the titanium was carried out in a purified argon atmosphere, the final purification being a bubbling through a 25/75 by weight sodium-potassium alloy. The titanium strip was supported in a graphite or a molybdenum boat, the individual pieces of strip being dusted with powdered calcium oxide to prevent them sticking together. The sintering temperature was 1,400° C., for various times.

The molybdenum and tungsten were sintered under a pressure of 0·1 micron at temperatures of 2,000° C. and 2,050° C., respectively, for 1 hour.

Density and Strength Measurements.

Density was determined on the green strip by weighing and mensuration, and on the sintered strip by a displacement method after the specimens had been impregnated with a 1% solution of silicone oil in benzene. Tensile properties were determined using a Chevenard micro-tensile machine :[7] the specimens were not annealed after preparation. Hardness measurements were made using a Reichert micro-hardness tester.[7]

Results

Titanium

General—The green strip varied in thickness from 0·49 to 0·44 mm., corresponding to the decreasing supply of powder at the end of the feed.

Specimens were furnace-cooled after sintering periods of 5½, 8, and 21 hours, and quenched after sintering for 23 hours at 1,400° C. The specimens sintered for 5½ hours were contained in a graphite cradle, the remainder in a molybdenum cradle. "High purity" argon was used for the 8 hour specimens, "commercial argon" for the remainder. Tensile specimens were prepared from strip sintered for 8 hours and for 21 hours : the remaining material was too brittle.

Previous work with copper micro-tensile specimens[7] has shown that unless the specimens are annealed after preparation, a true value for the percentage elongation cannot be obtained, because the edge of the specimen is in a work hardened state. Consequently, no values for

* Dr. Evans is now on the Staff of the Department of Chemical Engineering, Fuel Technology and Metallurgy in the Manchester College of Science and Technology.
† Kindly supplied by The General Electric Co., Ltd., Wembley.

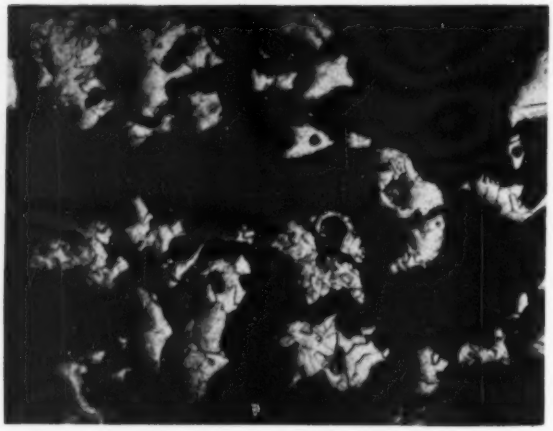
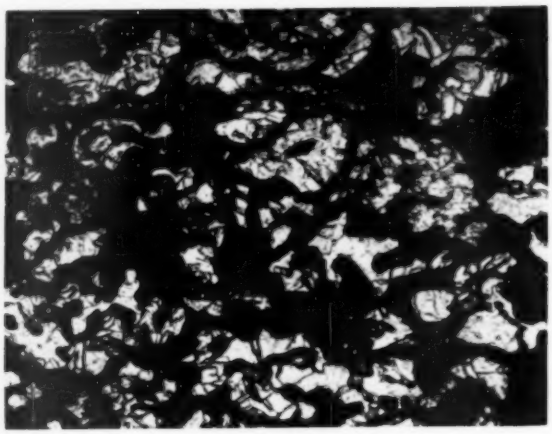


Fig. 1.—Uncompacted titanium powder—polished and etched. ×250



← ROLLING DIRECTION

Fig. 2.—Vertical section of 'green' titanium strip, parallel to the rolling direction—polished and etched. ×250

the percentage elongation of titanium are quoted. However, a specimen from the batch of strip sintered for 8 hours underwent 29% reduction by cold rolling without showing signs of cracking.

Density—Average densities obtained for titanium strip are given in Table I.

TABLE I.—DENSITY OF TITANIUM STRIP

Sintering Time (hr.)	Density (g./cc.)	Porosity (%)	Theoretical Density (g./cc.)
0	3·50	22·9	4·50
5½	4·35	4·2	—
8	4·34	4·4	—
21	4·41	2·9	—

Hardness—The results of hardness measurements for powder, for green strip and for sintered strip are given in Table II; a 23 g. load was used and each hardness quoted is obtained from the mean of ten impressions.

TABLE II.—HARDNESS OF TITANIUM STRIP

Material	Hardness (kg./sq. mm.)
Uncompacted powder	190
Green strip (surface, unetched) ..	241
Sintered for 5½ hours.	561
Sintered for 8 hours.	490
Sintered for 21 hours	426

Ultimate Tensile Stress—Values obtained for the ultimate tensile stress, with the corresponding density of the blank from which each tensile test piece was cut, are given in Table III.

TABLE III.—TENSILE STRENGTH OF TITANIUM STRIP

Material	Density (g./cc.)	Ultimate Tensile Stress (tons/sq. in.)
Sintered 8 hours	4·29	42·3
Sintered 8 hours	4·39	41·3
Sintered 8 hours and cold rolled 29%	—	57·0
Sintered 21 hours	4·41	16·6
Arc melted commercial titanium	4·5	29–47

Metallography—The uncompacted powder is shown in Fig. 1 and a vertical section of green strip parallel to the rolling direction in Fig. 2. Comparison shows that there has been some alignment of particles in the rolling direction, but no pronounced deformation is apparent. The polished but unetched surface of strip showed a few large pores and numerous small inclusions. Figs. 3–5 show the etched surface of strip sintered for 5½ hours, 8 hours and 21 hours, respectively (the large dark markings in Fig. 3 are surface stains). It can be seen that there is a slight but progressive increase in grain size and maximum pore size.

Thermal etching occurs during the sintering at high temperatures, as shown in Fig. 6, and this phenomenon has been discussed separately.[11] It is difficult to be certain as to whether the tensile specimens show a predominantly transcrystalline or intercrystalline fracture. The problem is probably irrelevant, since it is more likely that fracture occurs at that part of the cross section where stress concentration and pore area have a maximum value. The fracture would then be both transcrystalline and intercrystalline. After failure, both

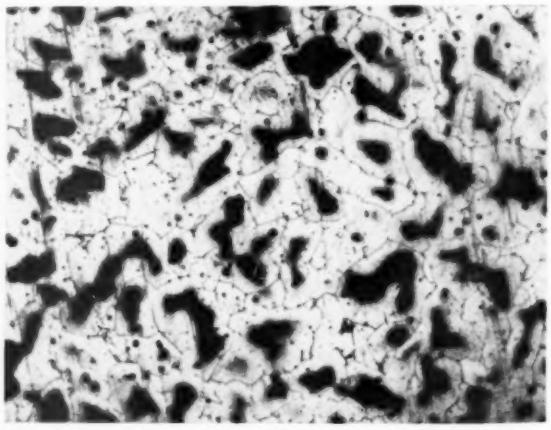


Fig. 3.—Surface of titanium strip sintered for 5½ hours—polished and etched. ×50

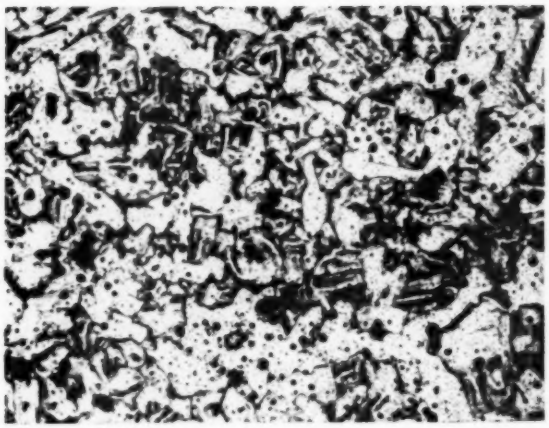


Fig. 4.—Surface of titanium strip sintered for 8 hours—polished and etched. ×50

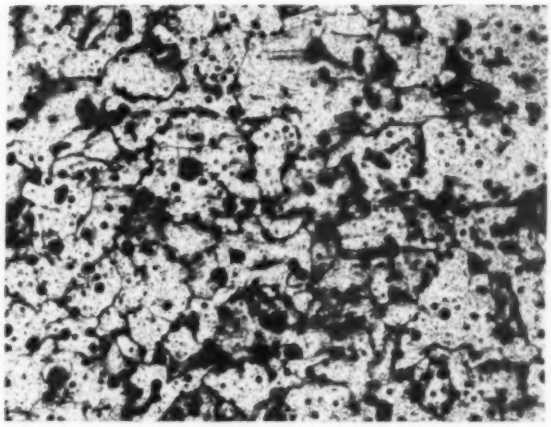


Fig. 5.—Surface of titanium strip sintered for 21 hours—polished and etched. ×50

specimens showed slip lines on the thermally etched surface.

Discussion—The titanium could be compacted into strip quite easily by rolling, and the figures obtained for strength are quite satisfactory considering the residual porosity. Compacting by rolling under the given conditions has increased the hardness of the titanium powder from 190 to 240 kg./sq. mm. due to the deformation, but the hardness after sintering is approximately double the latter figure. The cause is almost certainly the impure sintering atmosphere resulting in the titanium being exposed at high temperature to elements such as oxygen, nitrogen, hydrogen, or carbon, which can give rise to embrittlement. Even the material sintered for 8 hours must, by virtue of its high hardness and tensile strength, contain a proportion of impurity which was not initially present in the powder. A further source of these hardening and embrittling elements is the adsorbed gas initially present on the powder. Since 20% by weight of the powder used was −300 mesh, the surface area available for adsorption is very high. Entrapped air, even if a maximum porosity of 50% is assumed, cannot account for more than about 10^{-4}% of interstitial impurity.

Fig. 6.—Surface of titanium strip sintered for 21 hours—thermally etched during sintering. ×500

The presence of iron would also be expected to raise the ultimate tensile stress of the titanium.

With a better sintering atmosphere, the embrittlement caused by the pick-up of oxygen, nitrogen and hydrogen should be capable of being eliminated, with a consequent improvement in ductility and reduction in hardness.

Molybdenum and Tungsten

Results—The molybdenum green strip was fairly weak, but could be handled if care was taken. The tungsten strip was weaker, but could still be handled. After sintering, tensile specimens could be prepared from the molybdenum, but the tungsten strip was too brittle and cracked very readily. The results obtained are summarised in Table IV.

TABLE IV.—RESULTS OF TESTS ON SINTERED MOLYBDENUM AND TUNGSTEN STRIP

Material	Density (g./cc.)		Porosity (%)	Hardness 100 g.-load (kg.-sq. mm.)	Mean Ultimate Tensile Stress (tons/sq. in.)	
	Actual	Theoretical				
Green molybdenum ..	9·45	10·2	7·4	—	—	—
Sintered molybdenum	9·9	10·2	2·9	1532	—	26·35
Sintered tungsten ..	16·73	19·3	13·3	1605	—	—

The high density of the green molybdenum strip may be misleading, since this was determined by a displacement method, which is not the most accurate for green material.[7] The densities determined after sintering are subject to a smaller probable error. The difference in residual porosity between the molybdenum and tungsten is probably a result of the higher sintering temperature relative to the melting point.

The microhardness values obtained from the mean of ten impressions on sintered strip are remarkably high. The indentations are small even with a 100 gm. load, but the scatter is quite small.

The appearance of the polished and etched surface of green molybdenum strip is shown in Fig. 7. After sintering, the grain boundaries were delineated by thermal etching and a considerable increase in grain size occurred. There were, also, numerous striations, apparently cracks, which sometimes maintained direction

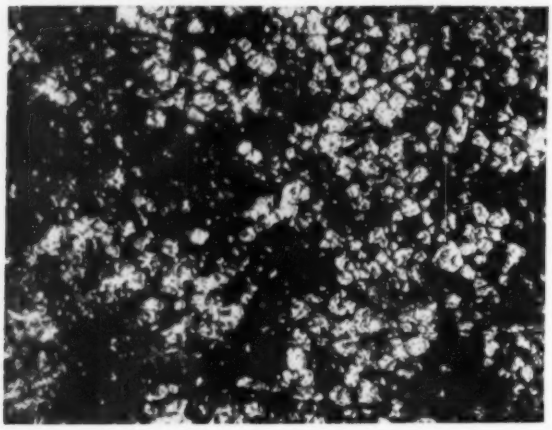


Fig. 7.—Surface of 'green' molybdenum strip—etched. ×500

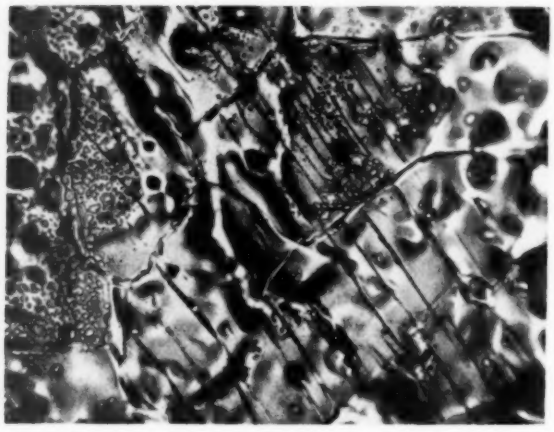


Fig. 8.—Surface of sintered molybdenum strip—thermally etched during sintering. ×500

across several adjacent grains (Fig. 8). The direction was not constant throughout the specimen, but they persisted, practically unchanged in appearance, after polishing and etching (Fig. 9). They may have a definite crystallographic orientation, since a high degree of preferred orientation is known to occur in rolled molybdenum sheet. The tensile fracture was composed of transcrystalline and intercrystalline regions.

The unpolished surface of sintered tungsten strip is shown in Fig. 10. The grain size is very small, as might be expected from the relatively low sintering temperature.

Discussion—From the rolling experiments it appeared that the molybdenum and tungsten powders available were not of an ideal size or size distribution, being generally too fine to give good flow—and hence compacting—properties. A wider size distribution and a coarser median particle size is desirable. Green strip from both powders was rather weak. This might not be too great a disadvantage if the rolling were immediately followed by continuous sintering, but for batch sintering some form of binder material would be desirable to impart strength to the green strip. A sintering atmosphere of hydrogen is probably preferable to vacuum sintering.

Acknowledgment

The authors are grateful to Professor G. Wesley Austin, O.B.E., formerly Goldsmiths' Professor of Metallurgy in the University of Cambridge, for his constant interest and encouragement in this work.

REFERENCES

1 Naeser, G. and Zirm, F., *Stahl und Eisen*, 1950, **70**, 955.
2 Franssen, H., *Metall*, 1954, **8**, 365.
3 Evans, P. E., and Smith, G. C., "Symposium on Powder Metallurgy 1954," Iron & Steel Inst. Special Report No. 58, p.131.
4 Franssen, H., *Metal Industry*, 1955, **86**, 227.
5 Evans, P. E., and Smith, G. C., *Sheet Metal Industries*, 1955, August.
6 Storcheim, S., *Metal Progress*, 1956, Sept., 120.
7 Evans, P. E., Ph.D. dissertation, "The Continuous Compaction of Metal Powders," Cambridge University, 1956.
8 Shaw, J. D. and Knopp, W. V., Proc. 13th Annual Meeting, Metal Powder Association, Chicago, 1957, Vol. 1., p.33.
9 Worn, D. K., at Informal Discussion on Powder Metallurgy, (Iron & Steel Inst. and Inst. of Metals), 1958, March 19th.
10 McQuillan, A. D. and M. K., "Titanium," Butterworths Scientific Publications, London, 1956, p.349.
11 Evans, P., *Acta Metallurgica*, 1957, **5**, (6), ,342.

Fig. 9.—Surface of sintered molybdenum strip—polished and etched. ×500

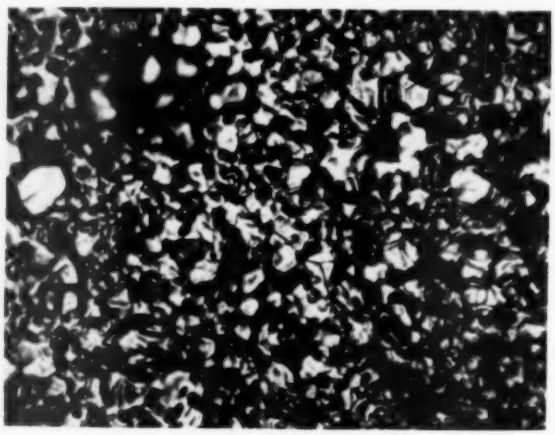


Fig. 10.—Surface of sintered tungsten strip—unpolished. ×500

The Effect of Surface Preparation on the Adhesion of Bearing Metal to Steel

By C. J. Thwaites, M.Sc., A.R.S.M., A.I.M.*

Steel bearing shells may be cleaned by grit or shot-blasting or by acid pickling prior to hot-tinning and lining with whitemetal. Whilst shot-blasting may provide adequate adhesion, preparation by pickling is to be preferred where maximum bond strength is required.

STEEL bearing shells are hot-tinned as a preliminary stage in the casting of whitemetal bearing alloys on to them. In preparation for hot-tinning, degreasing by recognised procedures is followed by pickling in suitable acids, or, alternatively, the shells may be shot- or sand-blasted. It has been said that shot-blasting before tinning produces a weaker bond between the bearing metal and the steel than chemical pickling, and this paper describes some experiments carried out at the Tin Research Institute to investigate this.

The four steels used in the experiments were plain carbon steels with carbon contents from 0·15% to 0·5%, and containing similar amounts of manganese, sulphur, phosphorus and silicon. Pieces 6 in. long × 3 in. wide × 0·25 in. thick were degreased in trichlorethylene vapour and then prepared for tinning by the methods shown in Table I. The pickling treatment used consisted of 10 minutes immersion in cold 66% by volume hydrochloric acid, followed by 2 minutes in cold 10% by volume nitric acid. A final dip for a few seconds in the hydrochloric acid was given before fluxing and tinning. Shot-blasting was carried out with angular, chilled cast-iron grit of 70 and 30 mesh, or with round iron shot of 50 or 30 mesh sizes, in a small, compressed-air type, hand cabinet. Grinding was carried out with a new, fine Carborundum wheel.

The degreased and prepared samples were then dipped in an aqueous flux solution containing :

Zinc chloride	24 lb.
Sodium chloride	6 lb.
Ammonium chloride ..	3 lb.
Hydrochloric acid	¼–1 pint
Water	10 gallons

Tinning was carried out at 300° C., the tin bath having an ebullient cover of ternary flux, containing the solid ingredients only of the flux dip, and activated regularly with a fine water spray. The tinned pieces were removed from the bath after about 10 seconds, and were then clamped firmly against one half of an ingot casting mould, as shown in Fig. 1. This mould had been preheated to 300° C. by immersion in the tinning bath. The whitemetal, containing 7% antimony, 3% copper, balance tin, was immediately poured into the mould aperture (Fig. 2) the temperature of the bearing alloy being 370–380° C. When the mould was full, a fine water-spray was played on the back of the steel to ensure directional solidification of the alloy from the bond outwards. Some "feeding" was required to prevent the formation of shrinkage cavities.

Chalmers-type bond strength tests were carried out as

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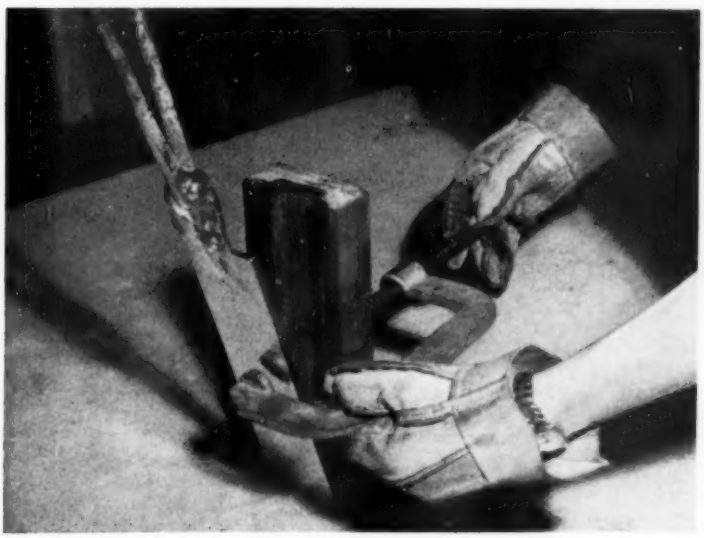

Fig. 1.—Clamping the tinned steel piece against the preheated chill mould.

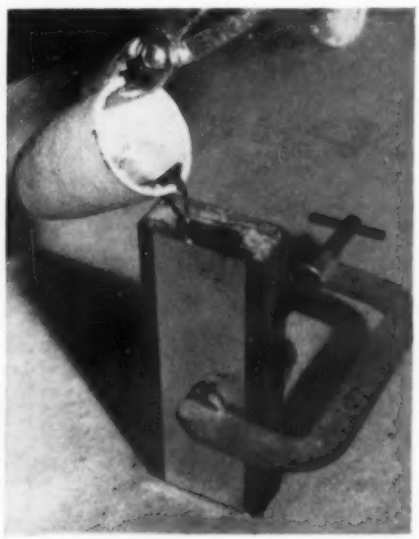

Fig. 2.—Casting the whitemetal into the mould cavity.

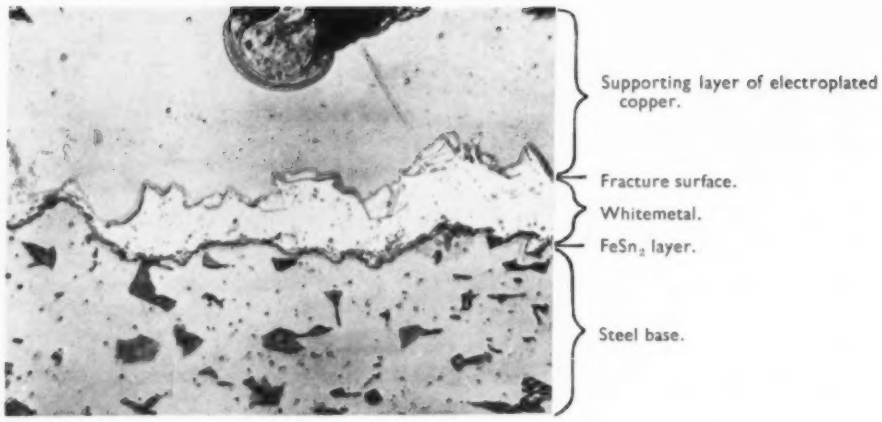

Fig. 3.—Whitemetal remaining bonded, after bond testing, to the surface of steel prepared by acid pickling. × 300

described elsewhere,[1] five determinations being made on each sample. The individual results and the mean bond strength obtained with the different modes of preparation of the steel are given in Table I. All values have been corrected to the nearest 0·1 ton/sq. in.

It will be observed that the bond strength values obtained with steel prepared by shot- and grit-blasting lie between 1·6 and 2·2 tons/sq. in., below those obtained with steel prepared by pickling. A surface treated by grinding gave a value about 1 ton/sq. in. below that for pickling, and a further reduction in adhesion resulted from light grit-blasting of the ground surface. When the full acid pickling cycle was given to samples initially prepared by grit-blasting or grinding, the adhesion increased until it was similar to that for the pieces treated solely by pickling.

The cause of the reduction in bond strength values due to shot- or grit-blasting was sought by metallographic examination of the whitemetalled steel pieces, but no obvious differences were seen. It had been thought that the shot-blasted surface, being heavily cold-worked, might cause more rapid growth of the layer of intermetallic compound, $FeSn_2$, and hence result in a weaker bond, but neither normal nor taper micro-sections[2]

TABLE I.—BOND STRENGTH TEST RESULTS

Pre-treatment of Steel	Carbon Content of Steel (%)	Individual Bond Strength Values (tons/sq. in.)	Mean Bond Strength (tons/sq. in.)
Acid pickled	0·15	6·1 6·0 5·5 5·8 5·8	5·8
	0·18 (En 32 B)	6·3 6·3 6·5 7·4 7·2 6·3 7·0 7·2 6·5 7·3	6·8
	0·34 (En 8)	6·4 5·3 6·2 5·8 5·3	5·8
	0·52 (En 9)	6·7 6·7 6·5 6·8 6·7 6·1 6·6 6·8 6·8 6·2	6·5
Shot-blasted with 70 mesh grit	0·15	4·4 3·9 5·4 4·0 4·0	4·3
	0·18 (En 32 B)	5·0 4·8 4·7 5·5 5·2 5·4 4·9 5·1 5·0 5·2	5·1
	0·34 (En 8)	5·1 4·7 4·1 4·1 3·6	4·3
	0·52 (En 9)	5·3 4·8 5·2 4·2 5·2 4·1 5·3 4·3 5·0 4·7	4·7
Shot-blasted with 30 mesh grit	0·15	4·1 4·3 5·7 4·5 4·1	4·5
Shot-blasted with 70 mesh grit followed by acid pickling as above.	0·15	5·7 5·4 5·3 5·6 5·8	5·6
Shot-blasted with 30 mesh grit followed by pickling as above.	0·15	5·6 5·9 5·7 5·8 5·8	5·7
Shot-blasted with 30 mesh shot	0·15	4·1 5·1 4·4 4·1 4·9	4·5
Shot-blasted with 50 mesh shot	0·15	3·9 5·1 2·1 4·8	4·0
Ground to a fine surface finish.	0·15	5·3 5·5 3·9 4·5 5·6	5·1
Ground to a fine surface finish, followed by light shot-blasting with 70 mesh grit.	0·15	3·8 4·4 4·6 4·3 4·9	4·4
Ground to a fine surface finish, followed by acid pickling as above.	0·15	5·7 5·8 5·8 5·4	5·6

showed any significant difference in the thickness or structure of the $FeSn_2$ layer.

Micro-sections of broken test-pieces were taken in order to search for possible differences in the mode of fracture of the bearing alloy from the steel base. Preliminary examination at a low magnification showed that, in the pickled steel, about 50% of the fracture had taken place through the whitemetal at a distance of about 0·001 in. from the alloy/steel interface, generally through crystals of copper-tin compound (Fig. 3). In the grit-blasted samples, however, fracture was virtually confined to the $FeSn_2$/steel interface.

Fig. 4 shows that with the steel prepared with 70 mesh grit, the bearing alloy has been pulled completely off the steel surface during testing, apart from traces retained in "pockets" in the irregular and "folded" surface resulting from the grit-blasting treatment. Fig. 5 shows, at a higher magnification, a fragment of whitemetal partially torn from the surface of steel prepared by grit-blasting, and it is clear that the layer of $FeSn_2$ has adhered to the bearing alloy but has stripped cleanly from the steel. Examination of the fracture surface of the

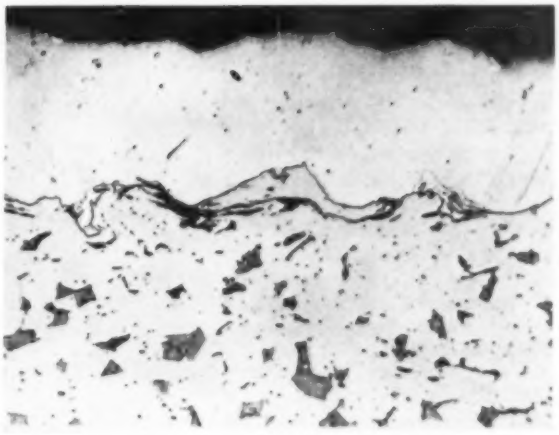

Fig. 4.—Surface of steel prepared by shot-blasting stripped free of whitemetal by bond testing. The sub-surface distortion of the steel by shot-blasting is also visible. ×300

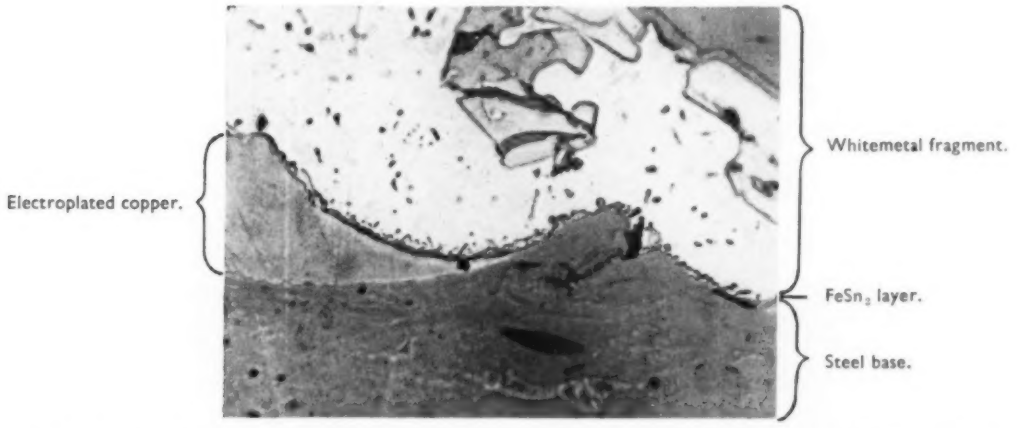

Fig. 5.—A fragment of whitemetal partially torn from the surface of the shot-blasted steel together with the layer of $FeSn_2$. ×1,500

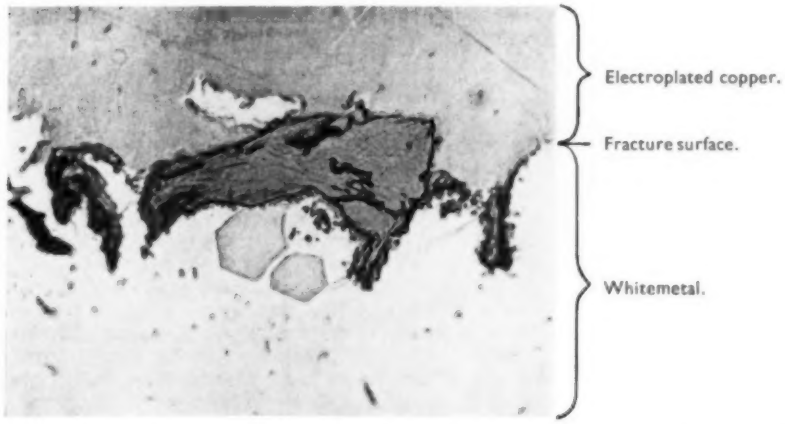

Fig. 6.—Particle of steel together with its associated $FeSn_2$ layer in the fracture surface of the whitemetal after bond testing. ×2,000

whitemetal shows that for all the grit-blasted specimens, the $FeSn_2$ layer was completely stripped from the steel, and, furthermore, large particles of what appeared to be steel were retained in the whitemetal surface. Fig. 6 shows such a particle and the $FeSn_2$ layer along the whitemetal-particle interface can be seen. The majority of the particles had a heavily-worked and laminated appearance (Fig. 7) similar to the grit-blasted steel surface seen in Fig. 3.

To establish that the particles were steel torn from the surface of the test-piece, the whitemetal fracture surfaces were tested by the Ferricyanide paper test[3]: a blue spot is formed on the impregnated paper by the presence of any free iron. Fig. 8 is a photograph of the test paper obtained on the grit-blasted samples showing the large number of spots caused by the presence of iron particles. The whitemetal pieces from samples given the acid pickling treatment, alone or after initial mechanical cleaning, showed no significant blue coloration of the Ferricyanide test papers.

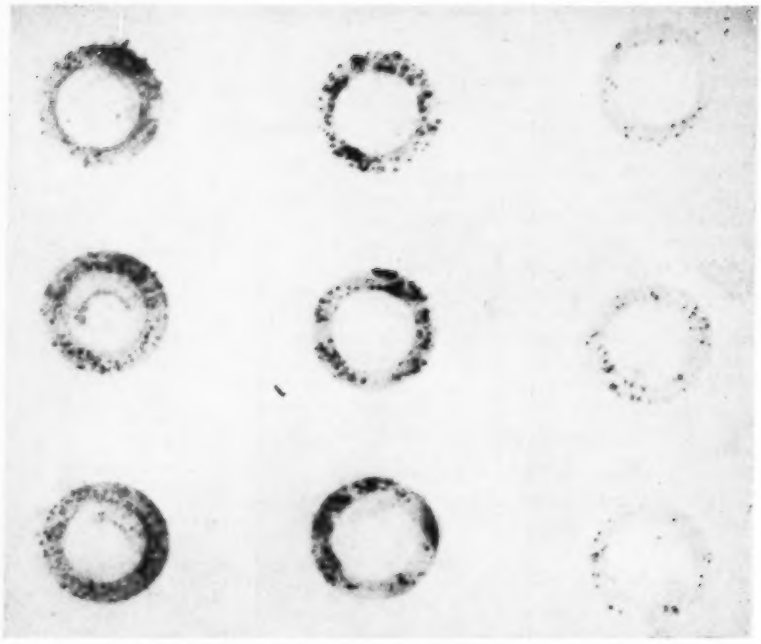

Fig. 8.—Ferricyanide paper test prints showing presence of iron particles in whitemetal fracture surface after bond testing. Left—steel treated with 70 mesh grit; centre—steel treated with 30 mesh grit; right—steel prepared by grinding.

It seems clear that shot-blasting causes severe distortion, folding and flowing of the steel surface, with the result that portions of steel surface have no appreciable bond to the parent metal. These are easily torn from the surface during adhesion testing, permitting a tearing stress to be exerted on the $FeSn_2$ layer, which is thus easily stripped from the steel, giving lower bond strength value. In the pickled samples, the bond is completely sound, and only a tensile stress is applied normally to the interfaces. The resistance to fracture is thus greater.

It has thus been shown that, if for reasons of convenience steel bearing shells are cleaned by grit- or shot-blasting instead of acid pickling, prior to hot-tinning and lining with white metal, a somewhat lower bond strength may be obtained. It must be made clear that the reduction in adhesion caused by shot-blasting may not preclude the use of this method of preparation, since the adhesion obtained is usually adequate. Where maximum bond strength is required, however, preparation by pickling would be preferred.

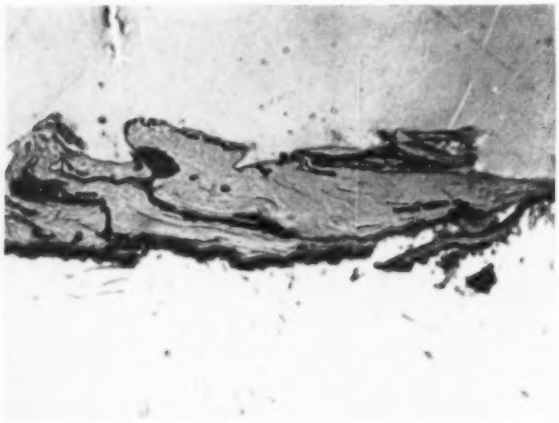

Fig. 7.—A larger particle of steel than that shown in Fig. 6, showing clearly the laminations and discontinuities caused by shot-blasting. × 2,000

The author is indebted to the International Tin Research Council for permission to publish this note.

REFERENCES

1. Thwaites, C. J. and Day, J. J., METALLURGIA, 1957, **56**, 263.
2. Eyre, B. L., METALLURGIA, 1958, **58**, 95.
3. Kerr, R., *J. Soc. Chem. Ind.*, 1942, **61**, 181.

Sales Reorganisation

HADFIELD'S LTD., announce that their home sales representatives are to act on behalf of the Hadfields group of companies as a whole, including Millspaugh, Ltd., and their subsidiaries. This arrangement does not include the celebrated Millspaugh pulp and paper making machinery or the plant for paper making works erected by Millspaugh-Wimpey. There is, however, an interesting range of engineering products made by the Millspaugh group, notably fabricated assemblies and centrifugally cast sleeves and rings in a variety of metals, the sale of whic hwill now be undertaken by representatives of the parent company, Hadfields, Ltd., East Heela Works, Sheffield. The Millspaugh group in Great Britain comprises: Millspaugh Ltd., Alsing Road, Sheffield, 9; C. A. Harden, Ltd., Hyde, Cheshire; Hargreaves & Jennings, Ltd., Tottington, Lancashire; Westbury Engineering Co., Ltd., Woolfold, Bury, Lancashire; and H. J. & A. Coulthurst, Ltd., Darwen, Lancashire.

Binary and Ternary Alloys of Tin with the Elements of Groups IIB, IIIB and VB of the Periodic Table

By H. W. Rayson, C. W. Goulding and G. V. Raynor

Department of Physical Metallurgy, University of Birmingham.

To examine the effect of third metals on the simple hexagonal tin-rich intermediate phases of the β_{Sn-Cd} type, tin-rich alloys of the systems tin-cadmium-zinc, tin-cadmium-thallium, tin-cadmium-bismuth and tin-indium-antimony have been examined by metallographic, X-ray, and electrical resistance methods. Experiments on the binary systems tin-cadmium, tin-zinc, tin-thallium and tin-indium were also carried out to clarify discrepancies in the literature. β_{Sn-Cd} dissolves comparatively little zinc or thallium, for which the closest distances of approach in the crystals of the elements differ appreciably from that for tin: approximately 0·7 at.-% zinc and 1·5 at.-% thallium dissolve at temperatures of 156° and 132° C., respectively. Although bismuth does not form a hexagonal tin-rich phase with tin, the β_{Sn-Cd} phase dissolves appreciable quantities of bismuth; at the same time the eutectoid temperature corresponding to the decomposition of β_{Sn-Cd} is lowered from 132·5° C. to a minimum of 86° C. At 125° C., the ternary phase based on β_{Sn-Cd} contains a maximum of about 9 at.-% bismuth, the solution taking place so as to maintain an electron: atom ratio close to that characteristic of β_{Sn-Cd} itself. Analysis of results in the literature for the tin-cadmium-antimony system shows that when antimony dissolves in β_{Sn-Cd}, a constant electron : atom ratio is again maintained. The results are briefly discussed and confirm the importance of atomic size and valency effects in the formation of the tin-rich hexagonal phases.

(*Continued from page 62 of the February issue*)

The Ternary Systems : Previous Work and Experimental Results

The System Tin-Cadmium-Zinc

PREVIOUS investigations[17] have dealt only with liquidus surfaces ; a ternary eutectic is formed at 163°C. and a composition 29·25% cadmium, 2·49% zinc. Many cooling curves showed an arrest in the solid state at about 120° C., which is associated with the eutectoidal decomposition of β_{Sn-Cd}, which had not been recognised at the time of this work.

Over eighty alloys were used in the present investigation ; the majority were near the β_{Sn-Cd} region of the equilibrium diagram. Most alloys were chemically analysed, and all results reported are based on analysed compositions.

Duplicate cooling curves with an alloy containing 25·22 at.-% cadmium and 6·94 at.-% zinc showed that the ternary eutectic, involving β_{Sn-Cd}, γ and δ, occurred at 159·25° C. An undercooled arrest corresponding to eutectoidal decomposition of β_{Sn-Cd} was observed at 120° C. ; zinc thus causes no marked lowering of the $\beta_{Sn-Cd} \rightarrow \alpha + \gamma$ eutectoid temperature. A series of solid alloys annealed at 158° C. for 2 hours showed no sign of chilled liquid in the microstructures, supporting the eutectic temperature derived from the cooling curves. Annealing experiments for 2 hours at 162°, 166° and 167·5° C. enabled isothermal solidus lines to be established, and these are shown in Fig. 7. An isothermal section at 156° C. was chosen for detailed metallographic examination. Little difficulty was experienced in distinguishing the α, β_{Sn-Cd}, γ and δ phases, which were the only constituents observed. The best reagent was a 2% solution of nitric acid in alcohol. On very light etching the β_{Sn-Cd} phase appeared a uniform grey, while the δ phase was darkened and the γ appeared light in colour. Deeper etching, which obscured small γ and δ particles, revealed the decomposition structure in the β_{Sn-Cd} grains, which, as in the binary system, could not be quenched unchanged. The isothermal diagram shown in Fig. 8 is based upon the microstructures of alloys annealed for 5 weeks, and the positions of the phase boundaries are supported by microstructures of other alloys too low in tin for inclusion.

To confirm the β phase boundaries, the electrical resistances of three series of alloys were determined at 156° C. The first series was intended to contain 0·1 at.-% zinc ; analysis showed that deviations from this value were slight. The curve of specific resistance against cadmium content was similar to that in Fig. 4. The tin-rich limit of the homogeneity range of β_{Sn-Cd} was ill-defined between the limits 3·9 and 4·1 at.-% cadmium, but the cadmium-rich limit was accurately established at 5·7 at.-% cadmium. The second series lay accurately on a line joining the compositions 0·5 at.-% zinc and 14 at.-% cadmium. The graph of specific resistance against cadmium content in this case defined the limits of the β_{Sn-Cd} phase as 3·75 at.-% cadmium at 0·4 at.-% zinc and 5·9 at.-% cadmium at 0·3 at.-% zinc, as shown in Fig. 9. The alloys for the third series were intended to

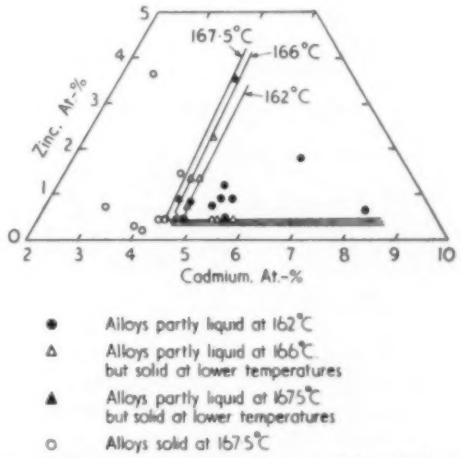

Fig. 7.—System tin-cadmium-zinc ; solidus isothermals.

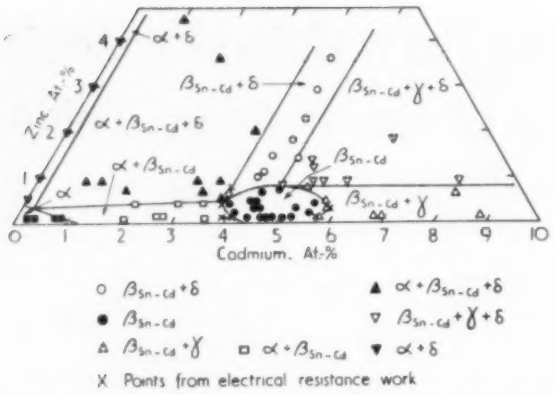

Fig. 8.—System tin-cadmium-zinc; 156° C. isothermal diagram.

have a zinc content of 0·75 at.-%, but analysis of the specimens in this case showed a scatter of approximately ± 0·15 at.-% about this composition. To obtain a plot of resistance against composition, therefore, the procedure adopted was to average the specific resistances of alloys of similar cadmium content, but whose zinc contents lay equidistantly on either side of the 0·75 at.-% zinc line in the composition diagram. Thus, an alloy with 3·47 at.-% cadmium and 0·88 at.-% zinc had a specific resistance of 18·96 microhm. cm., whereas an alloy with corresponding percentages of 3·78 and 0·59 had a resistance of 19·03 microhm. cm.; these were plotted as a resistance of 18·995 microhm cm. at 3·6 at.-% cadmium. The curve was similar to those already described, although the β_{Sn-Cd} phase does not quite contain 0·75 at.-% zinc. The first singular point was therefore taken to correspond with the $(\alpha + \beta_{Sn-Cd} + \delta)/(\beta_{Sn-Cd} + \delta)$ boundary; the cadmium-rich limit of the $(\beta_{Sn-Cd} + \delta)$ field at 0·75 at.-% zinc was insufficiently critically defined by the

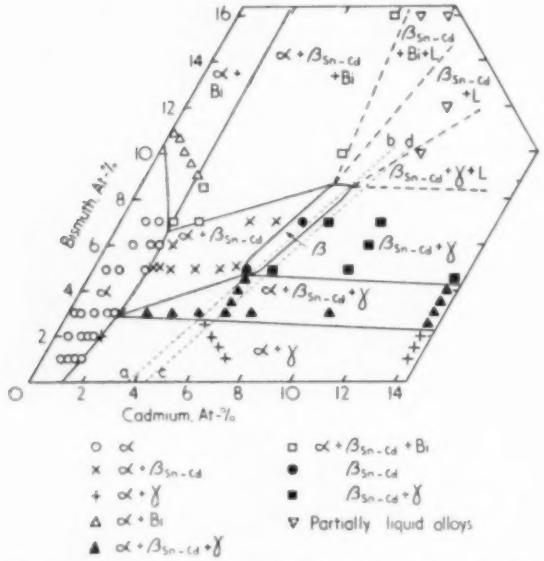

Fig. 10.—System tin-cadmium-bismuth; 125° C. isothermal diagram.

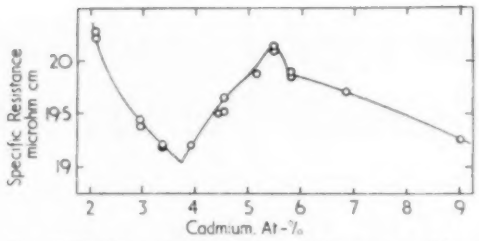

Fig. 9.—Variation of resistance with composition for ternary tin-cadmium-zinc alloys, at 156° C. Alloy compositions lie on line joining 0·5 at.-% zinc and 14 at.-% cadmium.

alloys used. The results of the electrical resistance work are included in Fig. 8, and are consistent with the metallographic work.

Annealing experiments were carried out to check the extension of the β_{Sn-Cd} field into the ternary diagram at 145° C. The β_{Sn-Cd} field was much more restricted than at 156° C. Thus, an alloy with 4·31 at.-% cadmium and 0·45 at.-% zinc contained both the β_{Sn-Cd} and δ phases, while the 3·89% cadmium, 0·27% zinc alloy fell in the $(\alpha + \beta_{Sn-Cd} + \delta)$ field. At 125° C. only the α, γ and δ phases could be recognised, confirming that zinc causes no very marked lowering of the eutectoid temperature.

There is thus only a limited solubility of zinc in the β_{Sn-Cd} phase, reaching a value of approximately 0·7 at.-% at 156° C. There is no tendency for the initial portions of the boundaries of the β_{Sn-Cd} phase, as zinc is added to the tin-cadmium system, to follow lines of constant electron : atom ratio; instead, they have an unexpectedly complex form. The first additions of zinc widen the homogeneity range appreciably, but above 0·1 at.-% zinc the $(\alpha + \beta_{Sn-Cd})/\beta_{Sn-Cd}$ and $\beta_{Sn-Cd}/(\beta_{Sn-Cd} + \gamma)$ boundaries approach each other. It may be noted that the solid solubility of zinc in β_{Sn-Cd} at 156° C. exceeds that in the primary solid solution.

The System Tin-Cadmium-Bismuth

Liquidus surfaces were investigated by Stoffel[18]; a ternary eutectic occurs at 103° C. and a composition 27·5 at.-% cadmium, 39·3 at.-% bismuth. No mention is made of the existence of the β_{Sn-Cd} phase.

In the present work, an alloy containing 40 at.-% bismuth and 27·5 at.-% cadmium was slowly cooled and thermal arrests were observed at 143° C. (liquidus), 115° C. (eutectic valley), 103° C. (ternary eutectic) and 78° C. The final arrest was well-marked, though supercooled, and was interpreted as due to eutectoidal decomposition of the β_{Sn-Cd} phase in the ternary alloys, indicating significant lowering of the binary eutectoid temperature by alloying with bismuth. The limit of safe annealing temperatures for examining the solid-state constitution was established by annealing alloys containing 3 at.-% bismuth for 2 hours at each of a series of temperatures from 109° to 177° C. The alloys contained from 0·05–20 at.-% cadmium, and no chilled liquid was detected after quenching from temperatures up to 155° C. At 160°–174·5° C., however, only alloys containing 5 at.-% cadmium or less remained solid, indicating a rapid fall of the solidus temperature between 5 and 6 at.-% cadmium at 3 at.-% bismuth. This suggested the existence of a β_{Sn-Cd} field containing at least 3% bismuth at near-solidus temperatures.

For the solid state work, a temperature of 125° C. was

chosen, partly to check the expected extension of the $\beta_{Sn\text{-}Cd}$ field towards lower temperatures; alloys were annealed for at least 4 weeks. Etching treatments with alcoholic ferric chloride, acidified 5% potassium-dichromate solution, or nitric acid in alcohol, sufficed to distinguish all the phases encountered. Bismuth particles appeared bright in a dark background after etching in ferric chloride, while γ was heavily attacked by the dichromate reagent. Distinction between α and $\beta_{Sn\text{-}Cd}$ was best achieved with nitric acid in alcohol. Difficulty was experienced owing to the tendency of bismuth to precipitate from quenched α and $(\alpha + \beta_{Sn\text{-}Cd})$ alloys at room temperature. Thus an alloy with 5 and 0·2 at.-% respectively of bismuth and cadmium, which was homogeneous α immediately after quenching, precipitated bismuth in the course of a few days. The adoption of methods by which sections of quenched α and $(\alpha + \beta_{Sn\text{-}Cd})$ alloys could be examined within twenty minutes of quenching enabled unambiguous results to be obtained, and the constitution of the tin-rich alloys is shown in Fig. 10, which is consistent with the microstructures of alloys too rich in solute metals for inclusion. The solid solubility of cadmium in tin is slightly increased by the presence of bismuth. The presence of $\beta_{Sn\text{-}Cd}$ at 125° C. is confirmed. Since bismuth dissolves only slight amounts of tin or cadmium, the $(\alpha + \beta_{Sn\text{-}Cd} + Bi)/(\beta_{Sn\text{-}Cd} + Bi)$ phase boundary extrapolates to a point very close to the bismuth-rich corner of the ternary composition diagram. This, together with the constitution of the alloy containing 10 at.-% bismuth and 7 at.-% cadmium, enables the bismuth-rich portion of the $\beta_{Sn\text{-}Cd}$ homogeneity range to be satisfactorily estimated.

Further alloys were annealed at 100° C., and the results are given in Fig. 11 for comparison with the more detailed work at 125° C. The $\beta_{Sn\text{-}Cd}$ phase is still present, though no homogeneous $\beta_{Sn\text{-}Cd}$ alloys fell within the composition range examined. After annealing for 5 weeks at 85° C., however, alloys contained only the α, γ and bismuth-rich phases, and no $\beta_{Sn\text{-}Cd}$ was observed. The $\beta_{Sn\text{-}Cd}$ eutectoid is thus lowered by bismuth to a temperature lying between 85° and 100° C., which is consistent with the supercooled cooling curve arrest referred to above.

Resistance/temperature experiments were used to define the ternary eutectoid more closely. Following preliminary experiments, wires prepared from five alloys containing 3–10 at.-% cadmium and 5 at.-% bismuth were heated slowly at approximately 10° C./day. Since preliminary work had indicated that steady resistance values are obtained after some 6 hours at temperatures of the order of 150° C., and that the resistances of air-cooled alloys reached a steady state after approximately 15 hours at room temperature, it was felt that this heating rate would allow a good approach to equilibrium. Resistance measurements were made at intervals of 5° C. or less, and the resistance/temperature curves showed that the ternary eutectoid involving the decomposition of the ternary $\beta_{Sn\text{-}Cd}$ phase into α, γ and bismuth occurred at 86° ±1° C., in good agreement with metallographic work.

The solubility of bismuth in the $\beta_{Sn\text{-}Cd}$ phase is thus considerable. The eutectoid temperature of the $\beta_{Sn\text{-}Cd} \rightleftharpoons (\alpha + \gamma)$ reaction is lowered, and in the ternary tin-cadmium-bismuth system $\beta_{Sn\text{-}Cd}$ exists at lower temperatures than that of the eutectoid in the binary system. Again, $\beta_{Sn\text{-}Cd}$ dissolves more solute metal, at a given temperature, than α.

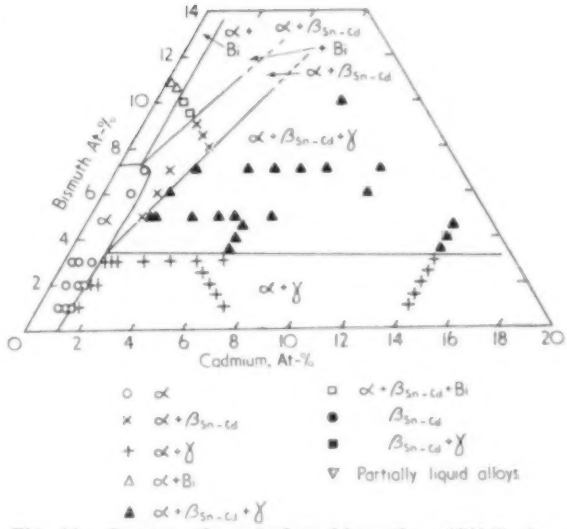

Fig. 11.—System tin-cadmium-bismuth; 100° C. isothermal diagram.

The System Tin-Cadmium-Thallium

The work of Jänecke[19] on the liquidus surfaces makes no reference to the existence of the $\beta_{Sn\text{-}Cd}$ phase; the system is of the simple ternary eutectic type, with eutectic valleys running from the temperatures and compositions of the binary eutectics to a ternary eutectic at 129·5° C.

In the present work a large number of alloys was examined by metallographic methods. As for the binary tin-thallium alloys, however, difficulty was encountered in the critical examination of polished or etched surfaces. In general, etching reagents revealed the grain structure of the alloys without adequate phase differentiation, unless a relatively large proportion of γ or the thallium-rich solid solution (ϵ) were present in the α or $(\alpha + \beta_{Sn\text{-}Cd})$ matrix. The α and $\beta_{Sn\text{-}Cd}$ phases were easily distinguished only when small amounts of $\beta_{Sn\text{-}Cd}$ occurred in an α matrix; where the matrix was β, the decomposed structure and the general tendency of reagents to stain the surface heavily, prevented the recognition of small amounts of other phases. Fig. 12* shows the results of experiments

* To avoid compression of the tin-thallium axis, the diagrams for the tin-cadmium-thallium system are plotted in weight percentages.

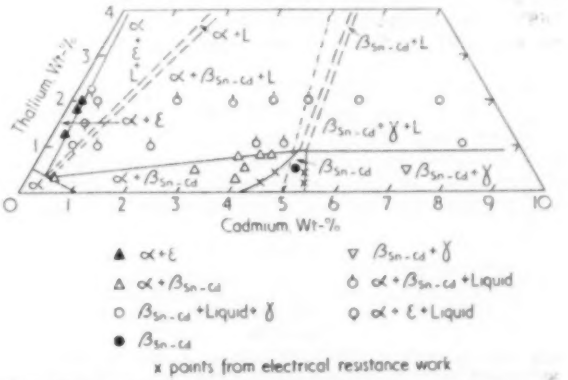

Fig. 12.—System tin-cadmium-thallium; 156° C. isothermal diagram.

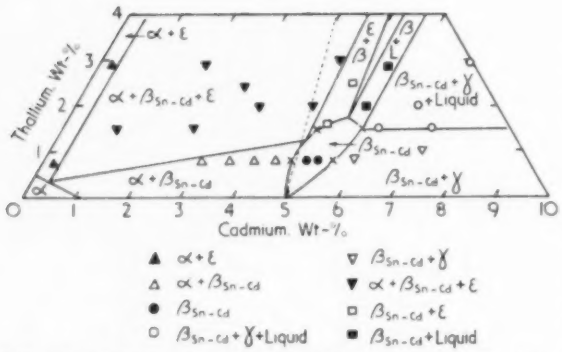

Fig. 13.—System tin-cadmium-thallium; 132° C. isothermal diagram.

on alloys quenched after 4 weeks at 156° C., in which certain identification of constituents could be made. Though these give an indication of the form of the diagram at 156° C., and show that β_{Sn-Cd} cannot contain more than about 0·9% thallium at this temperature, the $(\alpha + \beta_{Sn-Cd})/\beta_{Sn-Cd}$ and $\beta_{Sn-Cd}/(\beta_{Sn-Cd} + \gamma)$ boundaries are undefined.

To investigate these boundaries, three series of alloys, containing 3–7% cadmium and respectively 0·2, 0·4 and 0·6% thallium, were examined by the electrical conductivity method at 156° C. Reproducible results were obtained at 0·2 and 0·4% thallium. As the solidus was approached, however, increasing softness of the material, which allowed severe distortion at the knife edge contacts in the apparatus, made results unreliable. The graphs of resistance against composition for the 0·4% thallium series showed sharp changes in direction, which were identified with the required boundaries, which thus, for a temperature of 156° C., lie at 4·7 and 5·2% cadmium (0·4% thallium), and 4·5 and 5·3% cadmium (0·2% thallium). These values are included in Fig. 12, and show that the homogeneity range of the β_{Sn-Cd} phase narrows as thallium is added.

The ranges of solid alloys at 156° C. are confined to narrow regions close to the binary axes of the ternary isothermal diagram. Annealing experiments with a similar series of alloys at 145° C. showed that, in the composition range including β_{Sn-Cd}, alloys containing more than 1% thallium were again partly liquid. A temperature of 132° C. was therefore chosen for further study. After annealing for 4 weeks, the microstructures summarised in Fig. 13 were identified with certainty; as at 156° C., the boundaries of the β_{Sn-Cd} phase were studied by electrical conductivity measurements. Changes in

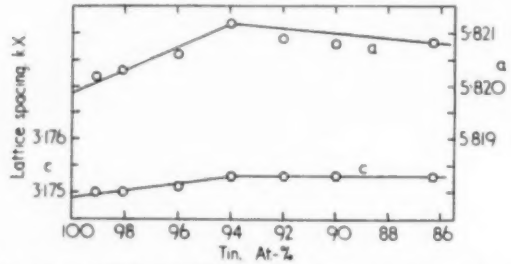

Fig. 14.—Lattice spacings of alloys, in the tin-indium-antimony system, containing indium and antimony in equal proportions.

direction of the curve of resistance against cadmium content were observed, for a constant thallium content of 0·8%, at 4·7 and 5·5% cadmium. Since alloys also containing 0·8% thallium and smaller quantities of cadmium lay in the $(\alpha + \beta_{Sn-Cd})$ field, these changes correspond to the $(\alpha + \beta_{Sn-Cd})/\beta_{Sn-Cd}$ and $\beta_{Sn-Cd}/(\beta_{Sn-Cd} + \gamma)$ boundaries, respectively. Similar direction changes in the plot for a series of alloys at 1·5% thallium were also observed. Since alloys with 1·5% thallium and 6 or 7% cadmium are partially liquid at 132° C., it is uncertain to which boundaries the critical points in the resistance/composition curve correspond. From the similarity of the resistance/composition curve to that for the 0·8% thallium series, it is probable that the changes in direction correspond to the $(\beta_{Sn-Cd} + \epsilon)/\beta_{Sn-Cd}$ and $\beta_{Sn-Cd}/(\beta_{Sn-Cd} + \text{Liquid})$ boundaries as shown in Fig. 13.

At 132° C., therefore, the solubility of thallium in the tin-cadmium β phase exceeds 0·8%, and may reach values of approximately 1·5%; this implies that the temperature of the $\beta_{Sn-Cd} \rightleftharpoons (\alpha + \gamma)$ eutectoid is lowered by thallium. The β_{Sn-Cd} phase does not exist, however, at 125° C.; alloys of compositions in the region of that of β_{Sn-Cd} were annealed for 6 weeks and quenched, and in no case was decomposed β present in the microstructures. The ternary eutectoid involving the decomposition of β_{Sn-Cd} thus lies between 125° and 132° C.

The System Tin-Indium-Antimony

Experimental work was confined to a limited survey of the effect of antimony on the α phase and the γ_{Sn-In} phase. Anticipating that equilibrium would be established between α and InSb, most attention was paid to alloys of compositions lying on the line joining the tin-rich corner of the ternary diagram to the composition of InSb. This compound has the zinc-blende structure, corresponding to 4 electrons per atom, so that the alloys lay along a line of constant electron : atom ratio if the valency of tin is assumed to be 4. The alloys were cast *in vacuo*, and for annealing, a temperature of 105° C. was chosen, to avoid the risk of introducing liquid from the relatively low-melting tin-indium alloys. After 6 weeks, the alloys were quenched; part of each alloy was reserved for X-ray work, and the remainder polished and examined metallographically. Etching in solutions of ferric chloride revealed large amounts of a hard white phase, *X*, in many alloys, but did not distinguish α and γ_{Sn-In} adequately. This distinction proved difficult, but no three-phase alloys containing both α and γ_{Sn-In} were encountered in the present work.

Along the line of constant electron : atom ratio 4, the first alloy to contain *X* contained 3·99 at.-% of both indium and antimony; the amount of *X* increased with decreasing tin content. All alloys of a further series lying along a line of constant electron : atom ratio 3·85 (assuming the valency of tin to be 4) were two-phase, consisting of γ_{In-Sn} and the hard *X*-phase recognised in the first series.

X-ray powder diffraction patterns were obtained from all alloys, after quenching from 105° C. The alloy containing 3·99 at.-% of indium and antimony gave a pattern, in agreement with metallography, in which only the lines characteristic of the tin-rich solid solution appeared in addition to those of one other phase. To examine the structure of the second phase, an alloy containing 40 at.-% of both alloying components was prepared. Metallographically, this alloy, after annealing at 105° C. and quenching, consisted largely of *X*. The

diffraction lines corresponded with a hexagonal structure of axial ratio approximately 1·64. All alloys with compositions corresponding to 4 electrons per atom contained only the α and hexagonal phases. Similarly, the diffraction patterns of all alloys lying along the 3·85 electron : atom ratio line contained lines from the γ_{Sn-In} phase of the tin-indium system and the new hexagonal phase only.

Lattice spacings were measured for alloys of the first series containing less than 14 at.-% solute. The results, plotted in Fig. 14, show that, along the 4 electron : atom ratio line, antimony has only a slight effect on the lattice spacings of tin. For this reason, the results cannot be used to establish the composition of the solid solubility boundary with certainty, but the fact that a maximum in the spacing is reached at 94 at.-% tin suggests that this composition is within the solid solution field, in conformity with the metallographic work.

The tin-indium-antimony system forms a contrast with the other ternary systems studied, in that the solubility of antimony in α exceeds that in γ_{Sn-In}. The solubility in γ_{Sn-In} must, according to metallographic work, be less than 2·5 at.-% antimony, whereas α can contain a maximum of 6 at.-% of solute. The hard white hexagonal phase X of axial ratio 1·64 is the dominating feature of the diagram. This axial ratio is characteristic of the wurtzite structure, which is closely related to that of zinc-blende, and also tends to form at the valency electron : atom ratio 4. This, and the general position of the two-phase fields concerned, suggest that X is connected with InSb. The zinc-blende structure of this compound may be changed to the wurtzite structure on the solution of tin. A second possibility, that the hexagonal phase is a ternary compound, is unlikely since, to date, no ternary compounds based on this structure have been reported. Fig. 15 represents the suggested form of the isothermal diagram at 105° C.

Discussion

Tin-rich intermediate phases with the simple hexagonal crystal structure are formed only in alloys of tin with cadmium, mercury and indium, and are thus confined to systems in which the solute metals have a lower group valency than that of tin and have similar closest distances of approach of atoms (d_c) in their crystal structures to that in white tin. Thus, corresponding phases are not formed in alloys with zinc, gallium, or thallium, for which the closest distances of approach of atoms differ considerably from that for tin, nor in alloys with antimony and bismuth, which, although of favourable size-factor with regard to tin, have group valencies higher than that of tin. These considerations, together with the observation by Raynor and Lee[4] that the axial ratios of the hexagonal phases vary smoothly with the number of electrons per atom, assuming group valencies of 2 for cadmium and mercury, 3 for indium, and 4 for tin, indicate that electronic factors, involving decrease of electron : atom ratio, are important. As noted by Raynor and Lee, the hexagonal structure is closely related to that of white tin, and an interpretation of the occurrence of the hexagonal phases, based on the effect of decreasing overlap of electrons across certain faces of the most probable Brillouin Zone for white tin, was put forward.

The present work emphasises the importance of both atomic size and valency factors in the formation of the phases of the β_{Sn-Cd} type. Table I summarises the closest distances of approach of atoms (d_c) in the crystal structures of the metals of interest, together with the assumed

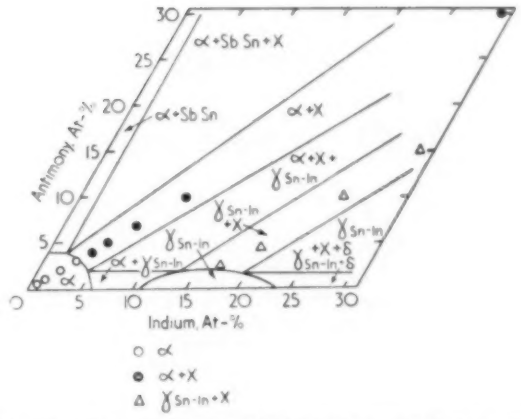

Fig. 15.—General form of 105° C. isothermal diagram for system tin-indium-antimony.

group valencies. d_c for zinc differs by 11·8% from d_c for tin, as compared with a difference of only 1·4% for cadmium. Fig. 8 indicates that, although the substitution of zinc for cadmium in β_{Sn-Cd} leaves the electron : atom ratio unaltered, the large difference between the d_c values is sufficient to prevent the solution of more than 0·7 at.-% of zinc at 156° C. For thallium, d_c is 12·7% greater than d_c for tin, and the solubility of thallium in β_{Sn-Cd} is correspondingly limited (Fig. 13). It is of interest here to note that the general direction of projection of the β_{Sn-Cd} field into the ternary isothermal diagram at 156° C. is consistent with the maintenance of an approximately constant electron : atom ratio, as shown by the broken line; in particular the $\beta_{Sn-Cd}/(\beta_{Sn-Cd}+\gamma)$ boundary lies at an almost constant electron : atom ratio.

The importance of the valency factor is more clearly revealed by the solution of elements of group V of the periodic table in β_{Sn-Cd}. The d_c values of antimony and bismuth are close to that of white tin, but the substitution of these elements in tin raises the electron : atom ratio, and the absence of a tin-rich hexagonal intermediate phase in the tin-antimony and tin-bismuth systems may be understood in terms of the hypothesis suggested by Raynor and Lee. The favourable atomic size relationships however suggest that antimony and bismuth should be soluble in the hexagonal structure, for which the electron : atom ratio has already been lowered by the inclusion of cadmium. The present work shows an appreciable solubility of bismuth in β_{Sn-Cd}, and a marked lowering of the β_{Sn-Cd} eutectoid decomposition. Bismuth thus has a stabilising influence on β_{Sn-Cd}. The striking feature of Fig. 10 is that the most probable boundaries of the ternary β phase at 125° C. lie close to lines of constant electron : atom ratio; the broken line *ab* in Fig. 10 represents the electron : atom ratio 3·924, corresponding to the tin-rich limit of the binary β_{Sn-Cd} phase at its widest extent (175° C.), while the broken line *cd* represents the ratio 3·912, characteristic of the tin-rich limit of β_{Sn-Cd} at

TABLE I

Metal	Closest Distance of Approach of Atoms, d_c (kX)	Group Valency
Sn (white)	3·016	4
Cd	2·973	2
Zn	2·6595	2
In	3·24	3
Tl	3·4010	3
Sb	2·898	5
Bi	3·105	5

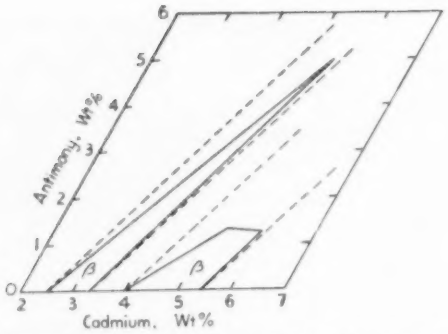

Fig. 16.—Homogeneity ranges of β_{Sn-Cd} in system tin-cadmium-antimony at 209° and 162° C., compared with lines of constant electron : atom ratio.

156° C. When bismuth dissolves in β_{Sn-Cd}, therefore, an electron : atom ratio is maintained which is closely similar to that of the binary phase itself, and the favourable size relationships permit approximately 9 at.-% bismuth to dissolve at 125° C.; the solubility at lower temperatures is greater.

The tin-cadmium-antimony system examined by Hansen and Pell-Walpole[20] shows a similar characteristic. In Fig. 16 the β phase areas at 209° and 162° C. are plotted, together with lines of constant electron : atom ratio corresponding to the limits of the homogeneity ranges of β_{Sn-Cd} in the binary system at the same temperatures. The solution of antimony clearly takes place in such a way as to maintain the electron : atom ratio approximately constant.

In the tin-indium-antimony system, the solubility of antimony in the γ_{Sn-In} phase is small, in contrast to the effects observed in the tin-cadmium-antimony system, in spite of the fact that all three metals are close together in the periodic table. This system is, however, not strictly comparable with the others considered, owing to the existence of the stable hard white phase, *X*, which is probably based upon InSb, and may be expected to affect the homogeneity ranges of other phases of the system.

The present work on the effect of third metals on β_{Sn-Cd} confirms earlier suggestions from the authors' laboratory that the formation of the hexagonal tin-rich intermediate phases can only occur with solute metals of lower group valency than tin, which have closest distances of approach of atoms, in their respective crystal structures, similar to that for tin. Once formed, however, the hexagonal phase is capable of dissolving metals of higher group valency than tin, in such a way that the electron : atom ratio remains approximately constant.

Acknowledgments

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REFERENCES

1 Hanson, D. and Pell-Walpole, W. T., *J. Inst. Metals*, 1936, **59**, 281.
2 Blade, J. C. and Ellwood, E. C., *J. Inst. Metals*, 1956, **85**, 30.
3 Gayler, M. L. V., *J. Inst. Metals*, 1937, **60**, 403.
4 Raynor, G. V. and Lee, J. A., *Acta Metallurgica*, 1954, **2**, 616.
5 Peirce, W. M., *Trans. A.I.M.E.*, 1922, **68**, 781.
6 Homer, C. E. and Plummer, H., *J. Inst. Metals*, 1939, **64**, 169.
7 Kurzyniec, E., *Bull. Acad. Polonaise Sci. Lett.*, 1938, (8–10A), 489.
8 Blondel, R., Publ. Sci. Tech. Ministère Air (France), 1936, No. 89.
9 Fuchs, P., *Z. Anorg. Chem.*, 1919, **107**, 308.
10 Mears, F. L., *Phys. Rev.*, 1931, (ii), **37**, 467.
11 Ireton, H. J. C., Blewett, J. P. and Allen, J. F., *Canad. J. Research*, 1933, **9**, 415.
12 Hanson, D. and Pell-Walpole, W. T., *J. Inst. Metals*, 1936, **58**, 299.
13 Bowen, E. G. and Morris-Jones, W., *Phil. Mag.*, 1931, (vii), **12**, 441.
14 Hägg, G. and Hybinette, A. G., *Phil. Mag.*, 1935, (vii), **20**, 913.
15 Davidson, A. C., Tech. Publ. Internat. Tin Res. and Dev. Council, A, No. 77, 1938.
16 Seltz, H. and Dunkerley, F. J., *J. Amer. Chem. Soc.*, 1942, **64**, 1392.
17 Lorenz, R. and Plumbridge, D., *Z. Anorg. Chem.*, 1913, **83**, 228.
18 Stoffel, A., *Z. Anorg. Chem.*, 1907, **53**, 167.
19 Jänecke, E., *Z. Metallkunde*, 1939, **31**, 170.
20 Hanson, D. and Pell-Walpole, W. T., *J. Inst. Metals*, 1937, **61**, 265.

Titanium Heating Coils in Chrome Plating

THE heating of chromium plating vats has always been one of the electroplating engineer's worst headaches. The usual method is by means of an external jacket carrying hot water or steam, but this is expensive in capital and maintenance costs, and maintenance is awkward because leakage of plating solution is difficult to detect. Furthermore, control of vat temperature is complicated by the high thermal capacity of the jacket. With such a system the plating vat responds only slowly to changes in input of heat to the jacket. Plastic linings cannot be used for the tank walls, since heat would not pass through them as quickly as through lead.

A much more convenient way of keeping the solution at working temperature would be to immerse a steam heating coil in the vat, but conventional materials, including plain, antimonial, or tin-bearing lead, give poor service owing to chemical attack, often accompanied by mechanical damage. This explains the increasing use which the plating industry is making of coils made from titanium tubing, which is available in a variety of diameters and gauges. Titanium, as strong as steel and half the weight, is completely inert to chromic acid, whether hot or cold, and steam coils with a wall thickness of the order of 20 s.w.g. will last indefinitely. Users have reported that vats can be heated with titanium coils in 25% less time than with lead coils of the same size.

The strength and lightness of titanium make simpler designs possible: for instance, supporting struts are usually unnecessary and a titanium coil weighing only 5 or 6 lb. has the same heat transfer capacity as a lead coil weighing about a hundredweight. Although titanium is a much more expensive material, because it is so easy to fabricate and because the components can be made many times lighter than in lead, in actual practice a titanium steam coil for a given duty costs little more than a lead one and lasts much longer in service. There is, therefore, ready financial justification for installing titanium heating coils in this and similar environments.

Simple units not requiring welding can be made from commercially available titanium tubing by anyone with a little experience in the bending of light-gauge tube, and more complex coils can be obtained from fabricating firms equipped with Argonarc welding facilities, or as standard items from manufacturers of electroplating plant.

Copper and Copper Alloys

A Survey of Technical Progress During 1958

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as raw material resources, extraction, fabrication, finishing and properties.

(*Continued from page 92 of the February issue*)

Properties

Copper

As a contribution to a symposium on the influence of residual elements on the properties of metals, Rhines[123] has reviewed the available information on the effects of impurities on copper in a very thorough manner. Bend tests by Klatte[124] have demonstrated the pliability of Liotorso copper, a highly poled cathode product deoxidised with lithium, which is claimed to be easier to produce than oxygen-free copper made in an inert atmosphere. Frost and Dugdale[125] describe the gradual spread of fatigue cracks in sheet copper, among other materials, using specimens which contained a small central slit.

Brasses

Vosskühler[126] has extended his review of the creep properties of brasses to cover those containing tin and aluminium. Izumi and Kawasaki[127] have found that additions of manganese and tin, either severally or together, considerably improve the spring properties of 60 : 40 brass, though iron impaired the cold working properties and was consequently detrimental from the point of view of spring manufacture. Expedients for neutralising the harmful effects of lead on the workability of both α and $\alpha + \beta$ brasses have been sought by Mal'tsev, Teplinskaya and Stepanova[128] who found that small additions of cerium, chromium or calcium were effective for the purpose.

Aluminium Bronzes

Tests by Dennison[129] on a 6·5% aluminium bronze of high purity have shown that, at 300° C., the finer the grain size the better is the creep and creep-rupture behaviour, though the reverse is true at 500° C. Hudson[130] has outlined the development of high-strength aluminium bronzes for marine propellers; further details of experience with propellers made from similar alloys have also appeared.[131]

Cast Bronze and Gunmetals

Kura and his associates[132, 133] have determined the general mechanical properties, including creep and fatigue, as well as such physical characteristics as density, electrical and thermal conductivities and thermal expansion for 80 : 10 : 10 leaded bronze, 85 : 5 : 5 : 5 leaded gunmetal, and U.S. Navy M-alloy, in the cast condition. The testing temperatures ranged from −40° to 290°C.

Alloys Containing Nickel

Comparative creep tests on copper, nickel and two cupro-nickels have been reported by Jenkins and Johnson,[134] who included an examination of the influence of loading rate and thermo-chemical history, as well as the effects of creep on necking behaviour, hardness and structure. Also concerned with copper alloys containing nickel is an excellent compendium of information on such materials compiled by Nothing.[135] Written in German, it carries numerous tables of data, and a useful list of trade names. Hegedus and Stefan[136] deprecate the presence of phosphorus as an impurity in nickel silvers, suggesting that it can be picked up from the linings of melting furnaces.

Alloys Containing Beryllium

It is well known that copper containing about 30% each of nickel and manganese responds well to heat treatment. A patent by the Beryllium Corporation[137] claims that the material can be further hardened by the addition of 0·38% of beryllium. Yans, Kaufman and Donaldson[138] have prepared beryllium sheet containing copper, among other elements, by powder metallurgy techniques. They found that copper improved the strength of the beryllium without greatly affecting the ductility.

Other Copper Alloys

The properties of several binary and more complex alloy systems based on copper have been investigated. Dreyer and Geissler[139] studied the precipitation hardening of copper containing 2·2% and 4·5% of cobalt, with and without the addition of 6–12% of manganese. Precipitation hardening is greater in the alloys containing manganese.

Copper-titanium and copper-zirconium alloys have been investigated by Dies,[140] who reports that an alloy containing 0·25% zirconium retained work-hardness at moderately elevated temperatures better than the conventional silver-bearing copper, and had high electrical conductivity. Copper alloys containing up to 2% of titanium, together with 0·3–1·2% of aluminium were found by Gruhl and Cordier[141] to evince considerable response to precipitation hardening, together with comparatively high ductility and good workability, both hot and cold.

A Japanese patent[142] covers dental alloy of golden colour containing 51–60% copper, 35–43% zinc, 0·3–2%

silicon and 0·5–5% of either iron or cobalt. Another patented material for special applications, namely for control rods in nuclear reactors, consists of copper containing 5–20% of boron and 25–79% of nickel or chromium.[143]

Copper in Steel

Grange, Lambert and Harrington[144] have carried out a careful investigation of the influence of up to 1·5% of copper on the behaviour of 0·48% carbon steel during heat treatment. They confirm that copper, in the amounts normally present in copper-bearing steels, promotes some degree of precipitation hardening, and show that it influences the response to tempering. When copper occurs merely as an impurity, however, they state that its influence upon heat treatment can be ignored.

Corrosion

Heat Exchangers

Breckon[145] has pointed out that the use of zinc or magnesium sacrificial anodes in connection with aluminium brass or cupro-nickel tubes for marine condensers and other heat exchangers may, in certain circumstances, prove detrimental. The author recommends iron or steel anodes, which in his experience have always given satisfactory service.

Engle, Reich and Shoults[146] have studied the use of acidic solutions for washing the tubes of condensers and heat exchangers. They found that turbulent rates of flow, which presumably lead to more efficient cleaning, do not unduly increase the rates of corrosion. An ingenious method which has been suggested for the cleaning of such tubes[147] is to circulate foam rubber balls with the cooling water.

Several valuable reviews may be commended to the attention of readers, notably those of Eichhorn[148] and Maurin[149] both of whom cover all aspects of the corrosion of copper alloy condenser tubes in considerable detail. Nothing[150] gives illustrated descriptions of the occurrence, nature and causes of selective corrosion in steam condensers, oil refineries and sugar refineries.

Cavitation Erosion

A report of a symposium on cavitation damage held two years ago in America has been published by Rheingans.[151] It includes data on various types of aluminium bronze, among other copper alloys. A valuable review of present knowledge concerning cavitation erosion has been issued by the Ministry of Supply under the authorship of Godfrey,[152] with special reference to the hydromechanical theory of the process, and to such factors as the influence of entrained and dissolved air and the mechanical properties of the material. Though a paper by Higgins[153] deals more specifically with tests on the resistance of cast iron to cavitation erosion, some data are included for aluminium bronze and 70 : 30 brass.

Stress Corrosion Tests

At the meeting of the International Standards Organisation in Harrogate, 1958, the Polish delegation put forward the view that an ammonia test for stress corrosion cracking should be formulated in addition to the mercurous nitrate test. It is significant, therefore, that a Polish paper by Niewiadomski[155] advocates the ammonia test, maintaining that the mercurous nitrate test is not entirely satisfactory. Schroeder[156] expresses the view that the mercurous nitrate test is suitable for cold worked material alone, whereas elastic strain is sufficient to give positive results with the ammonia test. Aebi[157] has devised a procedure for testing with an ammoniacal atmosphere controlled by means of the *p*H value of the solution, and a practical paper by Hellsing, Lissner, Rask and Ström[158] describes experiments with brass to assess the merits of the mercurous nitrate test and ammoniacal solutions in comparison with the results of prolonged storage.

Logan[159] has studied the relationship between crystal orientation and the incidence of stress-corrosion cracking in various brasses, while Warren and Beckman[160] deal with the sulphide corrosion cracking of high strength bolting materials, including wrought 6% aluminium bronze. Though not completely immune from cracking, this alloy was superior to most of the ferrous materials investigated.

Corrosion in Specific Environments

Alexander, Forgeson and their collaborators[161, 162] have reported an extensive investigation of the behaviour of fifty different metals and alloys in the tropical region of the Panama Canal, under atmospheric and marine corrosion. Limited in scope to coastal and industrial atmospheres was a somewhat similar South African programme reported by Godard.[163] Continuing the work of the United States Bureau of Standards on corrosion in soils, Romanoff[164] has given the results of tests on protective coatings, including tin on copper.

Jones[165] discusses the corrosion resistance of the non-ferrous metals normally used in buildings when exposed to the ordinary atmosphere, to acidic fumes, and to acidified water, and tabulates the causes of corrosion in various water-system components. Similar in theme, but concerned specifically with the behaviour of copper in buildings, is the paper of Baker and Carr,[166] who pay particular attention to natural and artificial patination of roofing sheet, and to the resistance of copper pipes to different qualities of water. They mention isolated cases in which ammonia vapour from nitrogenous foaming additions to concrete have led to stress-corrosion cracking in copper tubes. Halstead,[167] and also Peterson and Barnett[168] refer to the same matter.

The National Association of Corrosion Engineers[169] has collated data and experience on materials for the handling and storage of glacial and dilute acetic acid. Copper and copper alloys are classed with the austenitic stainless steels as satisfactory for most processing conditions. A tabulated summary of the behaviour of copper and copper alloys in about a hundred corrosive reagents has appeared.[170]

Protective Metallic Coatings

Britton and Michael[171] have found that the intermetallic compounds formed in hot-dipped or wiped coatings of tin on copper are resistant to corrosion, and may be slightly cathodic to copper in dilute neutral solutions. The outer layer of tin, however, remains anodic to copper even when ennobled by oxide films (see also ref. 164). Read[172] attributes the selective corrosion of copper under electro-deposited coatings of nickel and chromium to galvanic action, and includes photomicrographs showing, in cross section, the progress of corrosion in car bumpers which had been weathered out of doors.

Corrosion Inhibitors

Though inhibitors are rarely required in connection

with copper alloys, Machu and Fouad[173] have indicated that dezincification of 60 : 40 brass in acidic solutions can be retarded by their use. A British patent[174] of Swiss origin claims that a 0·1% aqueous solution of 2-guanidino-arylo-imidazole is a satisfactory corrosion inhibitor for copper and copper alloys.

Alloy Cast Irons

Tables have been published covering the properties of alloy cast irons, with particular reference to those which are resistant to corrosion.[175] Additions of copper are shown markedly to improve the resistance to sulphuric acid, while among the most popular heat resisting irons are those containing up to 7% copper with 18% or more of nickel.

Oxidation of Copper and Copper Alloys

Though a considerable volume of literature already exists on the oxidation of copper at elevated temperatures, Paidassi[176] has recently made a further contribution to this subject. As, on the other hand, comparatively little is known concerning the attenuated oxide films which form on metals at low temperatures, the work of Chessick, Yu and Zettlemoyer[177] in this field is of interest.

An experiment has been reported suggesting that the rate of oxidation of copper is retarded by light,[178] and a possible explanation is offered, based on the formation of a photocell between copper and cuprous oxide. Investigations of the elevated temperature oxidation of copper-manganese alloys[179] and of a 62 : 38 cupro-nickel (Constantan type)[180] have appeared.

Antifouling Paints

A publication by Bryson[181] gives comprehensive information on antifouling paints for ships' hulls, and states that cuprous oxide is considered to be the essential ingredient. In the U.S.A. it is almost the only poison used, though mercury oxide is often added in this country.

Joining

Welding and Brazing

Terry and Taylor[182] have discussed the welding of cupro-nickels and aluminium bronzes. They emphasise the merits of the inert gas shielded arc methods, but also draw attention to modern developments in metal-arc and gas welding practice, particularly in relation to the cupro-nickels. There can be little doubt that the welding of aluminium bronze presents some curious anomalies; for example Lancaster and Slater[183] report that welds made with 95 : 5 copper aluminium filler rods cracked badly, whereas those made with 93 : 7 were sound. Hemmes[184] gives practical information on the welding of silicon bronze and aluminium bronze by inert-gas shielded-arc methods, and a patent by Cresswell[185] claims that, in the case of alloys which, like aluminium bronze, form a refractory oxide skin, the application of electromagnetic vibrations during welding and cooling is beneficial.

Caplan and Nippes[186] have investigated fluxes for the brazing of aluminium bronze and Inconel. They have developed fluxes based on chlorides which can be readily removed by washing. Experiments by Munse and Alagia[187] have indicated the strength of lap and butt joints in several copper alloys, including silicon bronze, aluminium bronze and cupro-nickels, and Kenney[188] has described the brazing of galvanised iron with aluminium bronze. Fukuta[189] has patented a complex brass filler metal and suitable flux for brazing copper alloys to cast iron, while Clautice and Stevens[190] have evaluated the resistance of various joints between stainless steel and 70 : 30 cupro-nickel to repeated thermal shock in heat exchangers for submarine propulsion plant.

The welding of condenser and heat exchanger tubes into tube plates is becoming an increasingly important process. Wilson[191] describes developments in this direction with particular reference to cupro-nickels, aluminium brass, bronze, aluminium brass, Admiralty brass and copper. Kocher[192] discusses the combined use and joining of copper and steel in the manufacture of chemical equipment, paying attention to the welding of tubes into tube plates.

Patents covering silver solders and brazing alloys frequently appear. Among such publications are a straight copper-manganese alloy[193] and a silver solder containing manganese,[194] two other silver alloys[195, 196] one of which can be extruded, alloys based on copper with tin and titanium[197] and with nickel, chromium and boron,[198] respectively, and a flux-coated composite rod of copper and steel.[199]

Diffusion Bonding

The joining of copper to aluminium by means of liquid-phase sintering has been developed in Hungary.[200] The bonding medium is a layer of copper and aluminium powders in the proportions required to form the eutectic. According to Niemann[201] somewhat similar techniques can be used for the joining of beryllium copper to Monel.

Joints to Non-Metals

Peters and Lockwood[202] state that improved joints between polyethylene and rubber or brass can be made by means of a cement based on partially hydrogenated polybutadiene. The application of heat and pressure produces a strong vulcanised bond. Stuart[203] states that if copper or brass is brought into contact with substances containing sulphur, a film of sulphide is formed, and suggests that certain polymers which at present will not adhere to metals might be made to do so by the addition of a small percentage of sulphur. Comer[204] deals with glass-to-metal seals from the point of view of practical technology.

Powder Metallurgy

The Production of Copper Powder

An authoritative pronouncement by Mehl[205] describes the conditions which favour the production of copper powder by electro-deposition. In a companion paper, Watkinson[206] discusses the atomisation process. The author is concerned mainly with iron powder, but the principles are applicable also to copper. A recent patent[207] claims that copper of low bulk density can be produced by atomising copper containing small amounts of magnesium, calcium, lithium, zirconium or titanium. According to Whaley[208] finely divided copper, among other metals, can be made by reaction between sodium and the metal halides in organic solvents.

Sintering Processes

Alexander and Balluffi[209] have approached the sintering of copper powder by the use of fine wires wound together under slight tension. By metallographic examination they were able to trace the behaviour of the strands as they coalesced together. Pines and Sirenko[210]

have tested the mechanical properties of copper powder compacts at temperatures up to 900° C., and Johnson[211] gives data on the properties and microstructure of porous iron infiltrated with copper or with brass.

A British patent[212] covers the production of sheet from materials such as 11% tin bronze, by sintering while on a backing of heat-resisting steel, and subsequently stripping from the support; and another[213] claims that copper articles can be moulded from a doughy mass of copper powder and mercury, which hardens over a period of about 10 hours, and from which the mercury can afterwards be distilled away.

Roll-Compacting

Developments in the production of strip from copper powder include the use of heated rolls set obliquely to each other in a protective atmosphere[124]; preheating the powder so that it is actually rolled hot[215]; and uncoiling the strip from the sintering furnace directly into the rolls so that the second stage rolling process is performed hot.[216] Reports of commercial operations in the roll-compacting of copper continue to appear. Worn[217] has written a useful and practical appraisal of the present position, and developments have also been outlined by Shaw and Knopp[218] among others[219, 220, 221].

Powder Metallurgy Products

Zwilsky and Grant[222] have prepared various grades of sintered copper mixed with silica and alumina powders, and have examined their properties, including stress rupture tests at temperatures from 250° to 450° C. Wear tests on sintered copper containing additions of tin, lead, iron, silica and graphite have been carried out by Hofmann and Pieper,[223] and it is reported that products of this nature are finding increased application for clutch plates in the automatic transmissions of road vehicles.[224] Elliott[225] describes the manufacture of porous bronze bearings and infiltrated iron components.

More academic is the work of Tobin and Sinnott[226] on the technique of collecting and analysing small quantities of gas desorbed on heating metal powders, and also of Goldin and Juretschke[227] on the Hall constant, resistivity, and temperature variation of resistivity of copper samples with different porosities.

Physical Metallurgy

Constitution of Alloys

The theoretical work of Hume-Rothery and his collaborators on the correlation of the α-solid solubility of various elements in copper is well known. A recent paper[228] recapitulates much of the information he has obtained, and considerably extends present knowledge of the copper-arsenic equilibrium diagram.

Le Thomas and Cuvillier[229] have published a detailed study on the heat treatment of complex aluminium bronzes containing iron, nickel and manganese, and have shown that additions of iron and nickel tend to raise the temperature of the α-solid solubility limit. Hull and Garwood[230] have made a close study of the incidence and behaviour of the β-phase in copper-aluminium-nickel alloys, with special reference to the conditions which lead to the development of the martensitic type of structure, and martensitic transformations in drastically quenched aluminium bronze single crystals have been followed in detail by Chen[231] and recorded, in some cases, by means of motion pictures. Similar martensitic transformations in β-brass have been followed by Hornbogen and Wassermann.[232] Nickel[233] has determined phase boundaries in the copper-rich corner of the copper-aluminium-beryllium system.

Newkirk[234] has demonstrated that both γ-iron and α-iron are simultaneously precipitated from solid solution in copper containing 2·5% of this element, the γ-iron dominating the earlier stages. Vogel[235] has studied the ternary system based on copper, bismuth and sulphur, with emphasis on the pseudo-binary system formed by the sulphides of the two metals in question.

Heat Treatment

Japanese authors[236-240] have described the changes in electrical conductivity, hardness, and microstructure which take place when brass and various copper alloys containing small quantities of a wide range of added elements are annealed after cold work. Particular attention was paid to the early stages of recovery where "anneal-hardening" occurred, and much detailed information is recorded. Meechan and Sosin[241] have studied recovery phenomena in copper, gold and nickel after cold working at the temperature of liquid helium.

Chandrasekhar[242] has re-explored the annealing behaviour of copper containing small quantities of silver, and has substantially confirmed established knowledge on the subject. In contrast, Bassi[243] concludes that the solid solubility of bismuth in copper is at least 0·15% at 500° C. This is considerably higher than the accepted value, and is questionable in view of the marked embrittling effect of smaller quantities of bismuth at such temperatures.

Electrical and Magnetic Properties

Following his earlier work[244] on the influence of individual impurities on the electrical conductivity of pure copper, Pawlek[245] has studied the effects of multiple impurities. He found them to act cumulatively, provided that the limits of solid solubility in copper were not exceeded. Köster and Schüle[246] have determined the electrical conductivity and Hall constant for a considerable range of cupro-nickels and ternary alloys of copper, zinc and nickel, including the influence of cold work and heat treatment.

The magnetic susceptibilities of dilute copper-nickel alloys at low temperatures have been studied by Pugh and his associates,[247] and of cupro-nickels containing up to 24% of nickel by Torkar and Mariacher.[248] Becker[249] has traced the magnetic changes which take place during precipitation in a copper-cobalt alloy. A further contribution by the same author in collaboration with Livingston[250] has indicated that, in the early stages of precipitation, particle size and interparticle spacing can be deduced from magnetic measurements. With a more practical objective is the work of Bernstein[251] on the influence of iron, as an impurity, on the magnetic susceptibility of beryllium copper.

Of potential value in connection with the electrolysis of fused copper sulphide is the work of Bourgon, Derge and Pound[252] on conductivity of the molten sulphide (compare ref. 20).

Thermal Conductivity

Powell, Roder and Rogers[253] have determined the thermal conductivities at temperatures between −269° and 0° C. of coalesced, electrolytic tough pitch, phosphorus deoxidised and tellurium coppers, turning brass, and silicon bronze.

Density Measurements

Precision density measurements on a range of wrought copper-nickel alloys have been carried out by Gondo, Miyata and Kameno.[254] They correlate the results with those calculated from X-ray data. The specific volume (reciprocal density) of solid and liquid copper-lead alloys has been studied in Germany[255] in connection with the mode of solidification of such materials.

Diffusion and Related Phenomena

The vapour pressure of zinc over molten copper-zinc alloys has been determined by Everett, Jacobs and Kitchener,[256] who found negative deviations from Raoult's laws. Gupta, Basak and Chatterjee[257] have followed the evaporation of zinc from brass under heat treatment in vacuo, and Landergren[258] has reviewed the available information on self-diffusion in the copper-zinc system.

Using a degassing technique, Eichenauer and Pebler[259] have measured the diffusion coefficients and solubility of hydrogen in solid copper and aluminium at temperatures up to 650° C. and 525° C., respectively. The rate of diffusion of copper through molten lead over a wide range of temperature has been determined by Gorman and Preckshot,[260] who found it to be independent of the composition.

Physico-Mechanical Properties

The mechanism of fatigue failure continues to evoke the interest of research workers, and many publications on this subject appear. It is impossible here to do more than make brief mention of a few which seem to be of particular value. Broom and Ham[261] have demonstrated that the hardening induced in annealed polycrystalline copper and aluminium by cyclic stressing differs in nature from that arising from unidirectional deformation. Wood and Segall[262] have measured the proof stress required to produce a small alternating torsion of constant amplitude in annealed copper and brass, among other materials, and Forrest[263] has indicated that fatigue strength is slightly reduced by decreasing the cyclic speed. Cottrell and Hull,[264] and Hull alone[265] as well as Smith[266] have examined the incidence and behaviour of slip bands which lead ultimately to fatigue failure, while Clarebrough, Hargreaves and West[267] have determined the energy stored in fatigued copper. The fatigue strength of copper and other metals at sub-zero temperatures has been correlated with the ordinary tensile strength by McCammon and Rosenberg.[268]

Both in this country[269] and in Russia[270] work has been conducted on the influence of strain rate on the stress-strain curves of copper, and the effect on the plastic properties of copper crystals of coating with silver has been examined.[271] Brenner[272] has studied the plastic deformation of copper and silver " whiskers ".

Dayal[273, 274] deals with the fibre textures developed in face-centered cubic metals, including copper, when heavily cold drawn into wire, and Samuels[275] has studied the deformed layer produced on metal surfaces, including those of 70 : 30 brass, by machining, abrasion and polishing operations.

Nuclear Metallurgy

Meechan[276] has examined the influence of electron irradiation on the rate of change of electrical resistivity of cold-worked copper at temperatures between 100° C. and 150° C., and Boltax[277] has shown that neutron irradiation of precipitation hardened materials, such as beryllium copper and copper-iron alloys, favours re-solution of the precipitate.

Grain Boundaries

The attention of readers is directed to a book by McLean[278] covering the influence and general behaviour of grain boundaries in metals.

Chemical Analysis

The introduction of ethylene-diamine-tetraacetate (EDTA) has greatly facilitated the volumetric analysis of tin bronzes and gunmetals, particularly for control purposes in jobbing foundries and in connection with ingot manufacture. Kinnunen and Wennerstrand[279] describe its use and potentialities. A different approach to the problem of analytical control in small foundries has been advanced by Burford[280] who claims that tin, lead, zinc, nickel and phosphorus in copper alloys can be determined rapidly and with sufficient accuracy for normal requirements by centrifuging appropriate precipitates of these metals and measuring the volumes obtained.

Two methods for the volumetric determination of tin in copper-base foundry alloys have appeared,[281, 282] both based on iodometric titrations, as well as an improved iodometric procedure for the successive determination of copper and zinc.[283] Alfonsi[284] recommends electrolysis at controlled potential for copper alloys, and claims accurate results for the successive determination of copper, lead, tin and antimony in bronzes, high tensile brasses and bearing alloys. An improved method for the electrolytic determination of copper and lead in high-lead bronzes has also appeared.[285]

An accurate and relatively quick procedure for the analysis of complex silver solders, involving cation exchange and chromatographic separation of cadmium, has been developed by Jackson,[286] and a method for the simultaneous determination of iron, nickel and lead in blister and refined copper, which is claimed to be at once rapid and accurate, has been proposed by Barabas and Cooper,[287] while Dozinel[288] gives a modified thiocyanate procedure for the determination of iron in copper.

Wiedmann[289] has devised a rapid photometric method of determining titanium in copper, based on the red colour developed with chromotropic acid, and a potentiometric technique for the determination of manganese in copper alloys, worked out by Pohl[290], is based on the oxidation of manganous ions by permanganate.

A comprehensive review of current methods available for the analysis of non-ferrous alloys by chemical and physico-chemical techniques, but excluding spectroscopy, has been published by Milner,[291] and a comparable German publication[292] concentrates on the rapid, accurate and inexpensive methods available to modern industry.

Miscellaneous

Hygiene

Several elements used in small quantities in copper alloys are known to be detrimental to health. Among these are beryllium, cadmium and tellurium, concerning the toxic influences of each of which a paper has recently appeared. In dealing with beryllium and its compounds, Katherine Williams[293] pays far more attention to fluorescent lamps and similar articles than to the production

of beryllium copper alloys. Turner[294] surveys the causes and pathology of cadmium poisoning, on the basis of a long bibliography, and Banik[295] refers to the toxic nature of tellurium oxide evolved in grey iron foundries, rather than in the production of tellurium copper.

Music and Haberdashery

Descriptions of the manufacture of such items as musical instruments and zip fasteners can hardly help evoking interest. The firm of Boosey and Hawkes, Ltd.,[296] uses many interesting and ingenious techniques in the production of brass instruments, among which may be particularly mentioned the fashioning of complicated tubular shapes under internal pressure. The fabrication and operating principles of zip fasteners have also been comprehensively explained and illustrated.[297] The high strength of brass, its resistance to deformation, and the gold-like appearance which can be imparted to it, make this alloy the principal material for them.

Copper in Ancient Times

An interesting paper by Coghlan[298] describes copper mining activities in Britain during the Roman era, and another by Thompson[299] reconstructs the probable techniques used in prehistoric times for the extraction of copper from its ores and for the production of bronze. Maréchal[300] has examined certain copper tools from ancient Egypt containing up to 6 of 8% of arsenic. The addition tends to harden the copper, which, however, remains workable. The hardening effect of arsenic would be insufficient to account for the myth that the ancients had methods of hardening copper now lost to mankind.

Panseri and Leoni[301] report a metallographic and chemical study of ten mirrors found in tombs in various localities of Etruria, and dating from the 4th or 3rd century B.C., and Paret[302] refers to a find of sandstone moulds in Germany, dating from about 1,000 B.C. and evidently used for the casting of swords, knives, sickles, arrow-heads and hammers in copper or bronze.

A Pioneer

The recent exploits of the atomic powered submarine *Nautilus* recalls the fact that the first successful submarine bore the same name.[303] Built in 1800, the wooden hull of this vessel measured 20 ft. in length and 6 ft. in diameter. For protection, it was completely sheathed in copper.

REFERENCES

The Copper Development Association regrets that it is not in a position to make available, on loan or otherwise, any of the books or papers listed below. Anyone requiring to consult these should apply to one of the Technical Libraries in his locality.

123 Rhines, F. N., "Impurities in the Common Non-Ferrous Metals," Symposium on the Effect of Residual Elements on the Properties of Metals. Book, Publ. by A.S.M. 1956.

124 Klatte, H., "Tests on the Bending Value of High-Conductivity Oxygen-Free Copper (Liotorm copper) Wire," *Metall*, 1958, **12**, (2), Feb., 125-126. (In German).

125 Frost, N. E. and Dugdale, D. S., "The Propagation of Fatigue Cracks in Sheet Specimens," *J. Mech. Phys. Solids*, 1958, **6**, (2), 92-110.

126 Vosskuhler, H., "Creep Behaviour of Wrought Special Brasses. (Literature Survey Part IV). *Metall*, 1957, **11**, Nov., 944. (In German.)

127 Izumi, O. and Kawasaki, M., "Improvement of Copper Alloy Springs. II 60 : 40 Brass Series Containing Iron Manganese and Tin. III. Secular Change in Spring Materials of Brass Series," *Sci. Rep. Research Inst. Tohoku Univ.*, 1956 (A), **8**, (6), 493 ; 1957 (A), **9**, (1), 32. (In English.) *Metallurgical Abs.*, 1957, **25**, Dec., 245.

128 Mal'tsev, M. V., Teplinskaya, V. M., and Stepanova, M. V., "Neutralising the Deleterious Effect of Lead on Copper and Brasses," *Tsvet. Metally*, 1956, Pt. 7, 68 : *Referat. Zhur., Met.*, 1957, Pt. 8, 277. (In Russian.) *Metallurgical Abs.*, 1957, **25**, Dec., 228.

129 Dennison, J. P., "The Effect of Heat-Treatment on the Creep and Creep-Rupture Behaviour of a High-Purity Alpha Copper-Aluminium Alloy at 300° C. and 500° C.," *J. Inst. Metals*, 1957-58, **86**, Dec., 177.

130 Hudson, F., "The Development of High-Tensile Aluminium Bronze Alloys for Marine Propellers in Great Britain and the United States of America," *Intern. Shipbuilding Progress*, 1958, **5**, Mar., 139.

131 Anon., "Alloy Builds a Better Wheel," (Reprinted from *Motor Boating.*) *Nickel Bull.*, 1958, **31**, (3), Mar., 76. (Abstract.)

132 Kura, J. G. and Lang, R. M., "Mechanical and Physical Properties of Three Low-Shrinkage, Copper-Base Casting Alloys," Amer. Soc. Testing Materials, Preprint No. 86, 1958, 16 pp.

133 Simmons, W. F. and Kura, J. G., "The Creep Properties of Three Low-Shrinkage, Copper-Base Casting Alloys," Amer. Soc. Testing Materials, Preprint No. 85, 1958, 14 pp.

134 Jenkins, W. D. and Johnson, C. R., "Creep of Annealed Nickel, Copper, and Two Nickel-Copper Alloys," *Jnl. Res. Nat. Bur.* Standards, 1958, **60**, March, 173-191.

135 Nothing, F. W., "Nickel-Copper Alloys containing less than 50% Nickel," *N.I.B., Dusseldorf*, 1958, Publ. No. 7, 67 pp.

136 Hegedus, Z. and Stefan, M., "Production Defects caused by Phosphorus Impurities in Nickel Silver Alloys," *Acta Tech. Acad. Sci. Hung.*, 1958, **20**, (3-4), 297-304. (In Russian). *B.N.F. Bull.*, 1958, **38**, (349), Aug., No. 2056.

137 The Beryllium Corporation, (Inventors : S. Foldes and G. D. Kriebel). "Beryllium-Containing Nickel, Manganese, Copper Alloys," *U.S. Patent* 2,829,970.

138 Yans, F. M., Kaufman, A. R. and Donaldson, A. D., "Effect of Copper, Nickel, Iron and Chromium on the Tensile Properties of Preferentially Oriented Beryllium Sheet," *Jnl. Metals*, 1958, **10**, Feb., 96.

139 Dreyer, K. L. and Geissler, J., "Precipitation-Hardening and Recrystallisation of Copper-Rich Copper-Cobalt and Copper-Manganese-Cobalt Alloys. *Metall*, 1956, **10**, (21-22), 1028. (In German.)

140 Dies, K., "Strength Investigations on Copper-Titanium and Copper-Zirconium Alloys. *Metall*, 1957, **11**, Nov., 933. (In German.)

141 Gruhl, W. and Cordier, H., "Some Age-Hardenable Copper-Titanium-Aluminium Alloys," *Metall*, 1957, **11**, Nov., 928. (In German.)

142 Hayashi, M., "Dental Alloy with Golden Colour," *Japanese Patent* 3055/55.

143 Wall Colmonoy Corp. (Inventor : L. V. LaRou), "Alloy Containing B, Cu, Ni and/or Cr.," *Canadian Patent* 554,010.

144 Grange, R. A., Lambert, V.E. and Harrington, J. J., "Effect of Copper on the Heat Treating Characteristics of Medium-Carbon Steel," A.S.M. Preprint No. 62, 1957.

145 Breckon, C., "Cathodic Protection May Boost Corrosion," *Petroleum Refiner*, 1958, **37**, March, 189-190.

146 Engle, J. P., Reich, C. F. and Shoults, A. C., "Effect of Velocity of Acid Water on Condenser-Tube Corrosion," Paper to Engineers Society, Western Pa., 18th Annual Water Conf., Pittsburgh, 1957, October, 8 pp.

147 Anon., "Cleaning Condenser Tubes Continuously," *Engineering*, 1958, **185**, June 27, 828.

148 Eichhorn, K., "Corrosion Resistance of Copper and Copper-Alloy Tubes Used to Carry Sea Water," *Werkstoffe und Corrosion*, 1957, **8**, Aug./Sept., 453.

149 Maurin, A. J., "Corrosion Phenomena of Condenser Tubes," *Corrosion et Anti-corrosion*, 1957, **5**, Oct., 275 ; Dec., 383 ; 1958, **6**, Jan., 15. Paper to Assoc. des Ingenieurs d'Anticorrosion, April 9, 1957.

150 Nothing, F. W., "Corrosion, Cracking, and Erosion on the Outer Surfaces of Copper-Base-Alloy Condenser Tubes," *Metall*, 1956, **10**, (11-12), 520. (In German.)

151 Rheingans, W. J., "Resistance of Various Materials to Cavitation Damage," Amer. Soc. Mech. Eng. Publn., 1957, 27 pp.

152 Godfrey, D. J., "Cavitation Erosion : A Review of Present Knowledge (June, 1957). Ministry of Supply S. & T. Memo No. 17/57, Sept., 1957, 15 pp.

153 Higgins, R. I., "The Resistance of Cast Iron to Cavitation-Erosion," *B.C.I.R.A. J. Research*, 1957, **7**, Oct., 28. Res. Rept., No. 470.

155 Niewiadomski, C., "Stress-Corrosion of Brass," *Rudy i Metale Niezelazne*, 1957, **2**, (1), 13-20. (In Polish). *Met. Abs.*, 1958, **25**, (11), July, 864.

156 Schroeder, F. K., "Stress-Corrosion Experiments on Admiralty-Brass Condenser Tubes in Mercurous Nitrate Solution and Humid Ammoniacal Atmosphere," *Korrosion IX*, (Spannungskorrosion der Nichteisenmetall-legierungen), 1958, 68-72. *Met. Abs.*, 1958, **25**, (11), July, 865.

157 Aebi, F., "Investigations on the Stress Corrosion of Alpha-Brass in Ammonia Vapour. III. An Ammonia Method for Testing Brass Objects for Susceptibility to Stress Cracking," *Z. Metallkunde*, 1958, **49**, (2), February, 63-68.

158 Hellsing, S., Lissner, O., Rask, S. and Ström, B., "Comparative Study of Stress-Corrosion Testing of Brass and Long-Term Storage Tests," *Werkstoffe und Korrosion*, 1957, **8**, Oct., 569.

159 Logan, H. L., "Relationship between Crystal Orientation and Stress-Corrosion Cracking in Alpha- and Beta-Brasses." *J. Research Nat. Bur. Standards*, 1956, **56**, (3), 159.

160 Warren, D. and Beckman, G. W., "Sulfide Corrosion Cracking of High Strength Bolting Material," *Corrosion*, 1957, **13**, October, 631t-646t.

161 Alexander, A. L., *et al.* "Corrosion of Metals in Tropical Environments. 1. Test Method Used and Results Obtained for Pure Metals and a Structural Steel," U.S. Naval Res. Lab. Rept. No. 4929, 1957, 44 pp. PB121952.

162 Forgeson, B. W., *et al.* "Corrosion of Metals in Tropical Environments," *Corrosion*, 1958, **74**, February, 73t-81t.

163 Godard, H. P., "Five-Year Exposure of Metals to Atmosphere : Durban Experiment shows Resistance of Aluminium," *South African Eng.*, 1958, **49**, March, 37 and 39.

164 U.S. National Bureau of Standards and Romanoff, M., "Underground Corrosion. Part 2 : Behaviour of Protective Coatings in Soils," *Corrosion Tech.*, 1958, **5**, February, 45-48.

165 Jones, F. E., "The Resistance of Non-Ferrous Metals to Corrosion in Buildings," Paper read at the Symposium on "Corrosion of Metals in Buildings," arranged by the Corrosion Group of the Society of Chemical Industry at the Inst. of Civil Engineers, Mar. 21, 1957. *Chem. and Ind.*, 1957, No. 31, Aug. 3, 1050.

166 Baker, S. and Carr, E., "The Behaviour of Copper in Buildings," Paper read at the Symposium on "Corrosion of Metals in Buildings," arranged by the Corrosion Group of the Society of Chemical Industry at the Inst. of Civil Engineers, Mar. 21, 1957. *Chem. and Ind.*, 1957, No. 41, Oct. 12, 1332.

167 Halstead, P. E., "The Corrosion of Metals in Contact with Concrete," Paper read at the Symposium on "Corrosion of Metals in Buildings," arranged by the Corrosion Group of the Society of Chemical Industry at the Inst. of Civil Engineers, Mar. 21, 1957. *Chem. and Ind.*, 1957, No. 34, Aug. 24, 1132.

168 Peterson, H. B. and Burnett, J. C., "The Corrosive Effects of Protein-Type Foam-Forming Concentrates on Common Metals and Dissimilar Metal Couples," U.S. Naval Res. Lab. Rept. No. 4947, 1957, 19 pp. PB131018.

169 National Association of Corrosion Engineers. "Corrosion by Acetic Acid," N.A.C.E. Tech. Committee Report of Task Group T-5A-3 on Corrosion by Acetic Acid. *Corrosion*, 1957, **13**, November, 757t-766t.

170 Anon., "Corrosion-Resistance of Copper and Copper Alloys," *Ind. and Engg. Chemistry*, 1957, **49**, Aug., 63A.

171 Britton, S. C. and Michael, D. G., "The Corrosion of Tin and Tinned Copper in Dilute Neutral Solutions," *J. Appl. Chem.*, 1957, **7**, July, 349.

172 Read, H. J., "The Mechanism of Corrosion of Copper-Nickel-Chromium Coatings," *J. Electrochem. Soc.*, 1957, **104**, Aug., 168C; Abs. No. 56. Abstract only of paper to 112th Meeting, Electrochem. Soc.

173 Machu, W. and Fouad, M. G., "On the Behaviour of Brass in Dilute Dilute Mineral Acids and Their Mixtures in the Presence and Absence of Inhibitors," *Werkstoffe und Korrosion*, 1957, **8**, (3), 139. (In German.)

174 Geigy, J. R., A. G., "Process for the Protection of Copper and Alloys Thereof, and Corrosion Inhibiting Compositions," *British Patent* 784,039.

175 Anon., "Alloy Cast Irons Can Solve Tough Problems," *Materials in Design Engineering*, 1957, **46**, October, 140-144.

176 Paidassi, J., "Oxidation of Copper at 600-1,000° C.," *Acta Metallurgica*, 1958, **6**, March, 215-218.

177 Chessick, J. J., Yu, Y. F. and Zettlemoyer, A. C., "The Oxidation of Nickel, Cobalt and Copper at −78°, −22°, 0° and 26° C.," Preprints Proc. Second International Congress of Surface Activity, 1957, **3**, DD175-185.

178 Anon., "Retardation of Copper Corrosion by Light," *Nat. Bur. Stand. Tech. News Bull.*, 1958, **42**, Mar., 47.

179 Bouillon, F. and Jardinier, M., "Dry Oxidation of Copper-Manganese Alloys," *J. Chim. Phys.*, 1956, **53**, 817.

180 Sartell, J. A., Bendel, S., Johnston, T. L. and Li, C. H., "The Effect of Oxide Recrystallisation on the Oxidation Kinetics of a 62 : 38 Copper-Nickel Alloy," Amer. Soc. Metals, 1957, Preprint No. 47, 24 pp.

181 Bryson, H. C., "Ships' Paints' Faults," *Corrosion, Prevention & Control*, 1958, **5**, July, 47-52.

182 Terry, C. A. and Taylor, E. A. "Welding of Cupro-Nickel and Aluminium-Bronze Alloys," *Brit. Welding J.*, 1958, **5**, May, 211-225.

183 Lancaster, J. F. and Slater, D., "The Cracking of Aluminium Bronze Welds," *Brit. Welding J.*, 1958, **5**, May, 238-244.

184 Hemmes, P. L., "Inert-Gas-Shielded Arc Welding of Silicon and Aluminium Bronze," *Welding J.*, 1958, **37**, August, 779-788.

185 The British Oxygen Co. Ltd. (Inventor : R. A. Cresswell), "Fusion Welding of Metals and Alloys," *British Patent* 793,833.

186 Caplan, D. and Nippes, E. F., "High-Temperature Brazing of Aluminium Bronze to Inconel," *Welding J.*, 1957, **36**, Oct. 457-s.

187 Munse, W. H. and Alagia, J. S., "Strength of Brazed Joints in Copper Alloys," *Welding J.*, 1957, **36**, April, 177-s.

188 Kenney, C. V., "Tractor Company Welds Galvanized Iron with Aluminium Bronze," *Welding J.*, 1957, **36**, Aug., 811.

189 Fukuta, M., "Brazing of Cu Alloys to Cast Iron," *Japanese Patent* 5758/55.

190 Clautice, W. E. and Stevens, R. W., "Evaluation of Welded Joints Between A.I.S.I. 347 Stainless Steel and 70 : 30 Copper-Nickel Alloy Tubes under Thermal Shock, Specimen No. 3" U.S. Naval Engg. Expt. Sta. Rept. No. 080088E, 1955, 65 pp. PB 121877.

191 Wilson, R. A., "Development Covering the Welding of Non-Ferrous Tubes in Steam Surface Condensers," *Proc. Amer. Power Conference*, 1957, **19**, 279-284.

192 Kocher, R., "Combined Use of Steel and Copper in the Manufacture of Chemical Equipment," *Schweissen und Schneiden*, 1958, **10**, 206-209.

193 Electric Furnace Products Co. Ltd. (Inventor : L. E. Stark), "Weld Rod for Arc Welding," *German Patent* 1,024,313 (49b, 36/01) (E 6881).

194 American Platinum Works. (Inventors : R. Bayes and H. B. Aull), "Improvements in or Relating to Silver Brazing Alloys," *British Patent* 779,435.

195 Eutectic Welding Alloys Co. Ltd., "Brazing Alloy and Flux Composition," *British Patent* 782,307.

196 Westinghouse Electric Corp. (Inventor : R. E. Ballentine), "Extruded Phosphorus-Silver-Copper Brazing Alloys," *U.S. Patent* 2,795,520.

197 Revere Copper and Brass Inc. (Inventor : L. H. Hawthorne), "Welding" *U.S. Patent* 2,797,300.

198 Air Preheater Corp. "Copper Base Brazing Alloy," *British Patent* 789,655.

199 Phillips, C. E. and Dean, C. A., "Welding Electrode," *U.S. Patent* 2,817,751.

200 Erdmann-Jesnitzer, F. and Arnold A., "Joining of Aluminium and Copper by means of Liquid Phase Sintering of Aluminium-Copper Powder," (Verbinden von Aluminium mit Kupfer uber eine Sintering von Al-Cu-Pulver mit flussiger Phase). *Metall* 1958, **12**, (3), March, 179-185.

201 Niemann, J. T. *et al.*, "Diffusion Bonding below 1,000° F.," *Welding J.*, 1958, **37**, August, 337-s – 342-s.

202 Peters, H. and Lockwood, W. H., "Bonding Polyethylene to Rubber, Brass and Brass-Plated Metals," Bell Telephone System Tech. Publ. Monograph 2932, 1958, 10 pp.

203 Stuart, N., "New Aspects of Polymer-to-Metal Bonding," *Plastics*, 1956, **21**, (230), 308-311, 313. *Corrosion*, 1958, **14**, April, 109.

204 Comer, J., "Glass-to-Metal Seals," *Elect. Mfg.*, 1958, **61**, Mar, 110-114, 308.

205 Mehl, E., "Electrolytic Copper Powder," Paper presented to the Inst. of Metals and the Iron and Steel Inst. *Powder Metallurgy*, 1958, 1(1/2), 33-39.

206 Watkinson, J. F., "Atomisation of Metal and Alloy Powders," Paper presented to the Inst. of Metals and the Iron and Steel Inst. *Powder Metallurgy*, 1958, (1/2), 13-23.

207 Berk, F. W., & Co. Ltd., "Process for Producing Powders of Copper and Copper Alloys, *French Patent* 1,153,843.

208 Whaley, T. P., "Preparation of Metal Powders by Sodium Reduction," Paper to the Symposium on Handling and Use of the Alkali Metals, Amer. Chem. Soc., Dallas, 1956, April., p. 129. (Publ. 1957.)

209 Alexander, B. H. and Balluffi, R. W., "Mechanism of the Sintering of Copper," *Acta Metallurgica*, 1957, **5**, (11), 666.

210 Pines, B. Ya. and Sirenko, A. F., "Some Regularities in the Mechanical Strength of the Sintered Metals (Copper and Copper Mixtures). II. Testing at High Temperatures," *Zhur Tekhn. Fiziki*, 1956, **26**, (10), 2378. (In Russian.) *Metallurgical Abs.* 1957, **25**, Dec. 264.

211 Johnson, C. G., "Panel Discussion on Sintered Structural Materials: Copper or Copper-Base Infiltration of Iron Parts," *Proc. Metal Powder Assoc.*, 1956, p. 70.

212 Glacier Metal Co. Ltd. (Inventor : E. D. Liddiard), "Sintered Material," *British Patent* 784,153.

213 Hiensch, J. N., "Method of Making Shaped Metal Articles," *British Patent* 787,877.

214 Heck, F., "Improvements in and Relating to Rolling Mills for the Production of Strips or Bands from Metal Powder," *British Patent* 783,138.

215 Mannesmann, A. G. (Inventor : G. Nesser), "Process for Producing Strips, Wires, etc., from Metal Powders," *German Patent* 1,015,606 (491,12) (M22,534).

216 Sundwiger Messingwerk, "Process for Producing Strip by Rolling Metal Powders," *German Patent* 1,023,657 (491,12) (S48666).

217 Worn, D. K., "The Continuous Production of Strip by the Direct Rolling Process," Paper presented to the Inst. of Metals and the Iron and Steel Inst. *Powder Metallurgy*, 1958, (1/2), 85-93.

218 Shaw, J. D. and Knopp, W. V., "Current Developments in the Rolling of Both Ferrous and Non-Ferrous Powders," Proc. 13th Annual Meeting, 1957, Metal Powder Assoc., 1, p. 33.

219 Anon., "Production of Strip from Metal Powder," *Tool Engineer*, 1957, **39**, Aug., 91.

220 Anon., "Copper Sheet from Powder is Expected Soon," *Amer. Metal Market*, 1957, **64**, Nov. 9, 1. Report of papers to Metal Powder Assoc. Meeting, Nat. Metal Congress, Chicago, Nov. 8, 1957.

221 Anon., "Copper Strip from Powder," *Metal Bull.*, 1958, No. 4340, October 28, 14. *Iron Age*, 1958, **182**, (12), September 18, 109-110.

222 Zwilsky, K. M. and Grant, N. J., "Copper-Silica and Copper-Alumina Alloys of High Temperature Interest," *J. Metals*, 1957, **9**, Oct., 1197.

223 Hofmann, W. and Pieper, G., "Influence of Additions on Friction and Wear Properties of Sintered Copper," *Z. Metallkunde*, 1958, **49**, Feb., 80. (In German.)

224 Sintered Products Ltd. and Borg-Warner Ltd. "Sintered Bronze-Faced Clutch Plates," *Aut. Eng.*, 1958, **48**, Jan., 34.

225 Elliott, J. E., "Porous and Infiltrated Metal," *Metal Industry*, 1958, **92**, April 11, 293-296, April 18, 307-309, April 25, 334-336.

226 Tobin, J. C. and Sinnott, M. J., "Gas Desorption of Copper Powders," *Trans. Metallurgical Soc., AIME.*, 1958, **212**, April, 167-171.

227 Goldin, E. and Juretschke, H. J., "Hall Effect and Resistivity of Porous Copper," *Trans. Metallurg. Soc. AIME.*, 1958 **212**, June, 357-360.

228 Hume-Rothery, W. and Burns, J., "Liquid ⇄ Solid Equilibrium in Copper and Alloys; With an Appendix on the Equilibrium Diagram of the System Copper-Arsenic," *Phil. Mag.*, Series 8, 1957, **2**, Oct., 1177.

229 Le Thomas, P. J. and Cuvillier, J. (Mlle.), "A Dilatometric Study of Heat-Treatment of Aluminium Bronzes," *Fonderie*, 1956, No. 120, 28.

230 Hull, D. and Garwood, R. D., "The Martensite Transformations of the Beta Phase in Copper-Aluminium-Nickel Alloys," *J. Inst. Met.*, 1958, **86**, July, 485-492.

231 Chen, C. W., "Some Characteristics of the Martensite Transformation of Cu-Al-Ni Alloys," *J. Metals*, 1957, **9**, Oct., 1202.

232 Hornbogen, E. and Wassermann, G., "The Influence of (External) Stresses, and the Occurrence of Transformation Plasticity in the (Martensitic) Beta$_1$ →Beta" Transformation in Brass," *Z. Metallkunde*, 1956, **47**, (6), 427. (In German.)

233 Nickel, O., "Equilibrium Relationships in the Copper-Beryllium-Aluminium System. II. – Supplementary Investigations of Solubility Isotherms, Structure and Origin of Structure," *Z. Metallkunde*, 1958, **49**, (2), February, 57-62. (In German).

234 Newkirk, J. B., "Mechanism of Precipitation in a Cu-2·5 Pct Fe Alloy. *J. Metals*, 1957, **9**, Oct., 1214.

235 Vogel, R., "The System Bismuth Sulphide-Cuprous Sulphide and the Ternary System Bismuth-Bismuth Sulphide-Cuprous Sulphide-Copper," *Z. Metallkunde*, 1956, **47**, (10), 694-699. *Met. Abs.*, 1958, **25**, March, 501.

236 Mima, G. and Meshi, M., "Deformation and Annealing of Two-Phase Alloys. I. Alpha-Beta-Brass," *Nippon Kinzoku Gakkai-Si*, 1957, **21**, (1), 28. (In Japanese.) *Metallurgical Abstracts*, 1957, 25, Oct., 78.

237 Shinoda, G. and Amano, Y., "Anneal-Hardening Phenomena in the Grain-Boundary Region of Alpha-Brass." *Nippon Kinzoku Gakkai-Si*, 1957, 21, (1), 59. (In Japanese.) *Metallurgical Abs.*, 1957, **25**, Oct., 85.

238 Shinoda, G. and Amano, Y., "Electrical Resistance of Alpha-Brasses of Various Grain-Size in the Recovery Process." *Nippon Kinzoku Gakkai-Si*, **21**, (1), 62. (In Japanese.) *Metallurgical Abs.*, 1957, **25**, Oct., 85.

239 Suzuki, S., Matsuo, S. and Yanagisawa, M., "Recrystallisation, Ageing, and Anneal-Hardening of Copper-Aluminium Alloys Containing Zirconium or Titanium. *Rept. Gov. Indust. Research Inst., Nagoya*, 1957, **6**, (1), 18. (In Japanese). *Metallurgical Abs.*, 1957, 25, Oct., 85.

240 Suzuki, S., Matsuo, S. and Yanagisawa, M., "Effect of the Addition of Chromium, Cadmium, Indium, Antimony, Arsenic, or Phosphorus on the Anneal Hardening of Binary Alloys of Alpha-Phase Copper-Aluminium and Copper-Zinc," *Rep. Gov. Indust. Research Inst. Nagoya*, 1957, **6**, (3) 137. (In Japanese.) *Metallurgical Abs.*, 1957, **25**, Oct., 77.

241 Meechan, C. J. and Sosin, A., "Recovery of Electrical Resistivity of Cu, Au and Ni Following Cold Work at 4° K.," *Bull. Amer. Phys. Soc.*, 1957, **2**, Dec. 19, 388. Abstract N14 of paper to 1957 Winter Meeting of Amer. Phys. Soc., Stanford University, Dec., 1957.

242 Chandrasekhar, E. R., "Effect of Silver on the Recrystallisation Temperature of Electrolytic Copper," *Trans. Indian Inst. of Metals*, 1956-1957, **10**, 95.

243 Rassi, G., "Bismuth Precipitation in Copper," *Z. Metallkunde*, 1957, **48**, July, 394. (In German.)

244 Pawlek, F. and Reichel, K., "The Influence of Added Elements on the Electrical Conductivity of Copper. I. The Electrical Conductivity of Pure Copper : Its Maximum Value and the Influence of Additions," *Z. Metallkunde*, 1956, **47**, (6), 347. (In German).

245 Pawlek, F. Viessmann, K. and Wendt, H., "The Influence of Added Element on the Electrical Conductivity of Copper. II. The Influence of Multiple Metallic Impurities and Oxygen on the Electrical Conductivity of Copper," *Z. Metallkunde*, 1956, **47**, (6), 357. (In German.)

246 Köster, W. and Schüle, W., "Electrical Conductivity and Hall Constant. IV. Copper-Nickel Alloys; V. Copper-Nickel-Zinc Alloys," *Z. Metallkunde*, 1957, **48**, Nov., 592 : 595. (In German.)

247 Pugh, E. W., Coles, B. R., Arrott, A. and Goldman, J. E., "Magnetic Susceptibility of Dilute Alloys of Nickel in Copper Between 2·5 and 295° K." *Phys. Rev.*, Series 2, 1957, **106**, (3), 814.

248 Torkar, K. and Mariacher, H., "Note on the Reduced Normal Curve of Copper-Nickel Solid Solutions," *Z. Metallkunde*, 1956, **47**, (4), 260. (In German.)

249 Becker, J. J., "Precipitation and Magnetic Annealing in a Cu-Co Alloy," *Trans. Metallurgical Soc., A.I.M.E.*, 1958, **212**, Feb., 138.

250 Livingston, J. D. and Becker, J. J., "A Study of Precipitation-Hardening Employing Magnetic Measurements," *Trans Metallurgical Soc. A.I.M.E.*, 1958, **212**, June, 316-320.

251 Bernstein, H., "Reduction of Magnetic Susceptibility in Beryllium-Copper," *Trans. Metallurgical Soc. A.I.M.M.E.*, 1958. **212**, April, 225-226.

252 Bourgon, M., Derge, G. and Pound, G. M., "Conductivity and Sulfur Activity in Liquid Copper Sulfide," *J. Metals*, 1957, **9**, Nov., 1454.

253 Powell, R. L., Roder, H. M. and Rogers, W. M., "Low-Temperature Thermal Conductivity of Some Commercial Coppers," *J. Applied Physics*, 1957, **28**, (11), November, 1282-1288.

254 Gondo, Y., Miyata, N. and Kameno, T., "Precision Density-Measurement of Nickel-Copper Alloys, Pt. 1," *Sci. Rept. Yokohama Nat. Univ.*, 1956, Series I, Pt. 5, 29. (In English.) *Metallurgical Abs.*, 1957, **25**, Dec. 247.

255 Pelzel, E., "Copper-Lead Alloys. Part III. The Specific Volume of Solid and Liquid Alloys and Mode of Solidification," *Metall*, 1957, **11**, Nov., 954.

256 Everett, L. H., Jacobs, P. W. M. and Kitchener, J. A., "The Activity of Zinc in Liquid Copper-Zinc Alloys," *Acta Met.*, 1957, **5**, (5), 281. (In English.)

257 Gupta, K., Basak, P. and Chatterjee, G. P. "X-Ray Diffraction Studies of Alpha-Brass on Progressive Dezincification in Vacuum," *Trans. Indian Inst. Metals*, 1956-57, **10**, 157.
258 Landergren, U., "Diffusion on the Copper-Zinc System," *Jernkontorets Ann.*, 1956, **140**, (6), 401. *Metallurgical Abs.*, 1957, **25**, Nov., 151.
259 Eichenauer, N. and Pebler, A., "Measurement of the Diffusion Coefficients and the Solubility of Hydrogen in Aluminium and Copper," *Z. Metallkunde*, 1957, **48**, July, 373. (In German.)
260 Gorman, J. W. and Preckshot, G. W., "Molecular Diffusion and Interphase Transfer in the Solid Copper-Molten Lead System," *Trans. Metallurgical Soc. A.I.M.E.*, 1958, **212**, June, 367-373.
261 Broom, T. and Hamm, R. K., "The Hardening and Softening of Metals by Cyclic Stressing," *Pro. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 166.
262 Wood, W. A. and Segall, R. L., "Annealed Metals Under Alternating Plastic Strain," *Proc. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 180.
263 Forrest, P. G., "Speed Effect in Fatigue," *Proc. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 223.
264 Cottrell, A. H. and Hull, D., "Extrusion and Intrusion by Cyclic Slip in Copper," *Proc. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 211.
265 Hull, D., "Surface Structure of Slip Bands on Copper Fatigued at 293°, 90°, 20°, and 4·2° K.," *J. Inst. Metals*, 1958, **86**, May, 425-430.
266 Smith, G. C., "The Initial Fatigue Crack," *Proc. Roy. Soc.*, Series A. 1957, **242**, Oct. 29, 187.
267 Clarebrough, L. M., Hargreaves, M. E. and West, G. W., "The Energy Stored in Fatigued Metals," *Proc. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 160.
268 McCammon, R. D. and Rosenberg, H. M., "The Fatigue and Ultimate Tensile Strengths of Metals Between 4·2 and 293° K.," *Proc. Roy. Soc.*, Series A, 1957, **242**, Oct. 29, 203.
269 Baron, H. G., "Stress Strain Curves of Some Metals and Alloys at Low Temperatures and High Rates of Strain," *J. Iron and Steel Inst.*, 1956, **182**, (4), 354.
270 Vasil'ev, L. I., Butkevich, L. M. and Orekhov, E. I., "The Influence of the Velocity, and Amount of Plastic Extension on the Relaxation and Subsequent Deformability of Metals. I. (Copper and Aluminium). *Fizika Metallov i Metallovedenie*, 1956, **2**, (1), 142. (In Russian.) *Metallurgical Abs.*, 1957, **24**, June, 771.
271 Rosi, F. D., "Surface Effects on Plastic Properties of Copper Crystals," *Acta. Met.*, 1957, **5**, (6), 348. (In English.)
272 Brenner, S. S., "Plastic Deformation of Copper and Silver Whiskers," *J. Applied Phys.*, 1957, **28**, (9), 1023.
273 Dayal, P., "Preferred Orientations in Cold Drawn Face-Centred Cubic Metal Wires," *Trans. Indian Inst. of Metals*, 1956-57, **10**, 201.
274 Dayal, P., "Zonal Texture of Drawn Face-Centred Cubic Metal Wires," *Trans. Indian Inst. of Metals*, 1956-57, **10**, 211.
275 Samuels, L. E., "A Study of the Deformed Layer Produced on Metal Surfaces by Mechanical Machining, Abrasion and Polishing Operations," *Electroplating*, 1957, **10**, Sept., 279; Oct. 315.
276 Meechan, C. J., "Annealing of Cold Worked Copper by Electron Irradiation," *J. Applied Physics*, 1957, **28**, Feb., 197.
277 Boltax, A. "Effects of Radiation Damage on Precipitation-Hardening Alloys, with Special Reference to Copper-Iron Alloys," Amer. Soc. Testing Materials Special Tech. Pubn., No. 208, 1957, 183.
278 McLean, D., "Grain Boundaries in Metals," 1957. Oxford Univ. Press, 346 pp.
279 Kinnunen, J. and Wennerstrand, B., "Analysis Control of Tin Bronze and Gun Metals," *Foundry*, 1958, **86**, July, 97.
280 Burford, W. A., "Simple Analytical Control for Small Foundries," *Brit. Foundryman*, 1958, **51**, June, 280-282.
281 "Fonderie", "Rapid Determination of Tin in Bronzes," *Fonderie*, 1957. No. 141, Oct., 465. (In French.)
282 Bischitzky, F., "Volumetric Determination of Tin in Copper Alloys," *Metall*, 1956, **10**, (21/22), 1041. (In German.)
283 Ligny, C. L. de and others., "An Improved Iodometric Method for the Successive Determination of Copper and Zinc," *Analyt. Chim. Acta*, 1957, **16**, June, 516.
284 Alfonsi, B., "Electrolysis at Controlled Potential Analysis of Main Alloys of Copper," *Metallurgia Italiana*, 1957, **49**, Feb., 89. (In Italian.)
286 Anon., "The Determination of High-Lead Contents in Bronzes," *Fonderie*, 1956, No. 120, 33.
286 Jackson, E., "The Analysis of Silver Solder Alloys," *Metallurgia*, 1957, **56**, Dec., 307.
287 Haraldsæ, S. and Cooper, W. C., "Determination of Iron, Nickel and Lead in Blister and Refined Copper," *Metallurgia*, 1957, **56**, Aug., 101.
288 Donzinel, C. H., "Photometric Determination of Iron in Pure and Electrolytic Copper," *Metall*, 1956, **10**, (21/22) 1042. (In German.)
289 Wiedmann, H., "Rapid Photometric Determination of Titanium in Copper (and Aluminium) Alloys," *Z. Metallkunde*, 1957, **48**, (7), 410-412. *Met Abs.*, 1958, **25**, March, 544.
290 Pohl, H., "Comparative Determination of Manganese in Copper and its Alloys (a potentiometric method)," *Metall*, 1957, **11**, (11), November, 947-949. (In German).
291 Milner, G. W. C., "Non-Ferrous Metallurgical Analysis: A Review," *Analyst*, 1956, **87**, (968) 619.
292 Boltz, G., Wiedmann, H. and Kurella, W., "Modern Methods in Non-Ferrous Metal Analysis," *Metall*, 1956, **10**, (17/18), 821.
293 Williams, K., "The Hazards of Beryllium and Its Compounds," *Indust. Chemist*, 1957, **33**, (386), 191.
294 Turner, F. M., "Cadmium Poisoning," Atomic Energy Research Est., Report A.E.R.E., M/D/M17, 1957, 10 pp. H.M.S.O.
295 Banik, E., "Difficulties with Tellurium in the Foundry," *Giesserei*, 1956, **43**, (15), 400.
296 Boosey & Hawkes Ltd., "Sounding Brass," *Welding and Metal Fab.*, 1958, **26**, July, 259-265, August, 281-288.
297 Anon., "Zip Fasteners," *Cuivre, Laitons, Alliages*, 1957, Pt. 36, 19-23.
298 Coghlan, H. H., "Roman Mining in Britain," *Optima*, 1958, Mar., 8.
299 Thompson, F. C., "The Early Metallurgy of Copper and Bronze: A Report to the Ancient Mining and Metallurgy Committee of the Royal Anthropological Institute," *Man*, 1958, **58**, January, 1-7.
300 Maréchal, R., "(Ancient) Egyptian Copper Tools," *Metaux-Corrosion-Ind.*, 1957, **32**, (379), 132-133. *Met. Abs.*, 1958, **25**, March, 567.
301 Panseri, C. and Leoni, M., "The Manufacturing Technique of Etruscan Mirrors," *Met. Ital.*, 1957, **12**, (4), 233.
302 Paret, O, "The Remains of Moulds from a Bronze Foundry of 3,000 Years Ago," *Giesserei*, 1956, **43**, (7), 159.
303 Fulton, R. "The *Nautilus*," *Engineer*, 1958, **206**, August 29, 333.

Semi-Conductor Grade Silicon Production

I.C.I. has brought into operation a large-scale development plant for the manufacture of high-quality silicon of semi-conductor grade. This remarkable material, which costs over £100 per pound, has become of commercial importance in the manufacture of semi-conductor devices, such as transistors, which are fast replacing conventional thermionic valves in many applications. The I.C.I. plant is operated by its General Chemicals Division on Merseyside, and by the middle of this year capacity will approach 4,000 lb. per annum: plans for much larger production are well advanced.

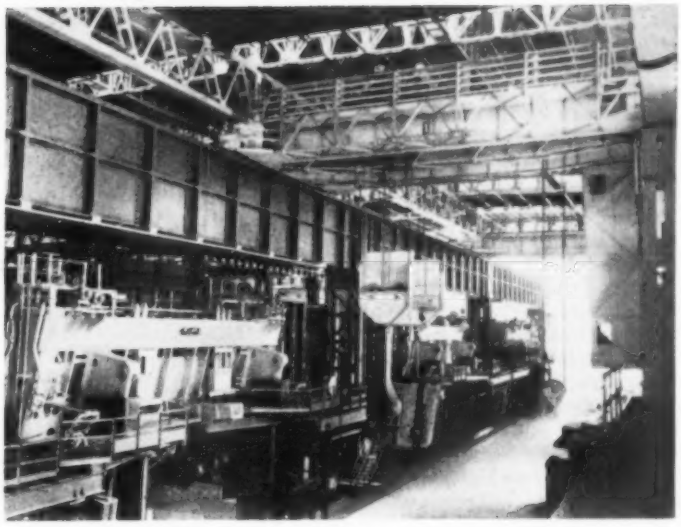
The use of silicon—a silvery-grey substance of metallic appearance—has developed greatly during the past ten years in the electronic field for the manufacture of semi-conductor devices for rectification and amplification. Such devices are much smaller and lighter than conventional radio valves and their life, depending neither on a heated filament nor on a vacuum, is likely to be much longer. Moreover, their power requirements in use are negligible. Examples of important applications are in rocket equipment, in electronic computing machines, which at present contain several thousand valves, and in smaller items of electrical equipment such as portable radio and television sets and deaf aids. The use of silicon rectifiers enables much valuable space to be saved in power stations and on traction vehicles. Germanium is also used in semi-conductor devices, but silicon is becoming the preferred material. It has greater stability at elevated temperature, a higher reverse voltage rating, and it operates with much smaller reverse currents.

Although compounds of silicon are the main constituents of the earths crust, the pure element required for semi-conductors is expensive. This is because of the extreme purity required—impurities of a few parts in one thousand million are sufficient to spoil the semi-conductor properties. To attain such purity, expensive plant construction materials, expensive distillation stages, and costly controls are needed. The production of pure silicon is, however, only one stage in the manufacture of a semi-conductor device, and at present the cost of the silicon is only a small part of the whole. The silicon in the device is in the form of a thin wafer cut from a single crystal of silicon. This crystal can be grown either by pulling from melted silicon contained in a quartz crucible, or by a method called floating-zone refining, whereby a molten zone is moved through a solid bar of silicon. Silicon is normally required in lump form for crystal pulling and in rod form for zone refining.

I.C.I. can supply silicon in either form. Lump silicon, p-type, of resistivity greater than 200 ohm. cm., is now available in quantity. Silicon in rod form for zone refining, deposited direct from vapour and of exceptionally low boron content, is being produced in limited quantities in lengths of 24 in. and in diameters up to 1 in. If the future market requires it, I.C.I. is prepared to supply silicon in rod form already zone refined into single crystal rods. To date, much of the silicon used in Britain has come from America or France. Now I.C.I. will be able to satisfy the demand in Britain and at a later stage expects to enter the export field.

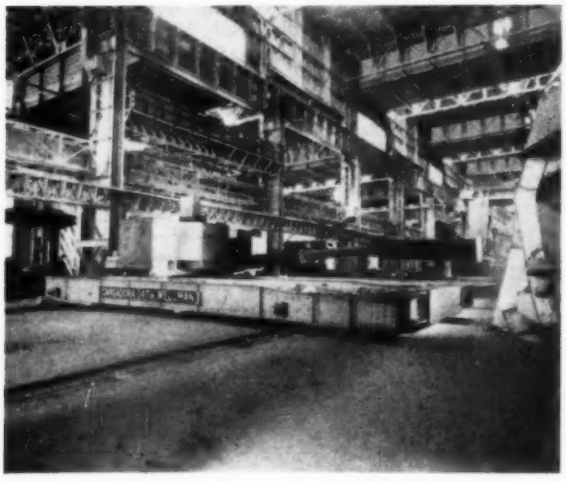
Expansion of Spanish Steel Industry

New ENSIDESA Melting Shop at Aviles Commissioned



A general view of the three Wellman 350-ton tilting open hearth furnaces and one of the four 140-ton ladle cranes.

AN important step in the expansion of the Spanish steel industry has recently taken place with the commissioning of the three 350 ton tilting open hearth furnaces in the melting shop of the new integrated iron and steelworks at Aviles on the Asturian coast. The works is operated by the Government-sponsored company ENSIDESA (Empresa Nacional Siderurgica S.A.) and comprises coke-ovens, blast furnaces, steelmaking plant and rolling mills. A considerable amount of the equipment has been supplied and erected by members of M.E.E.C.O., the consortium of British steelworks engineering firms. The first blast furnace has been operating since November 1957, and produced iron for sale until the commencement of steelmaking. The rolling mills are due to start up in the very near future, and in the meantime ingots are being manufactured on a limited scale for sale and stock. This is enabling the melting shop personnel to be thoroughly trained in the operation of the furnaces before full scale production is required. A small number of British steelmakers are assisting in the working of the furnaces and training the Spanish personnel.



One of the two 4-ton ground type revolving open hearth furnace charging machines.

The steelmaking units comprise a 600 ton active mixer and three 350 ton tilting open hearth furnaces, which, together with the stockbay cranes, ladles cranes, charging machines, and other ancilliary equipment have been supplied by The Wellman Smith Owen Engineering Corporation, Ltd. The tilting furnaces are designed to operate on a high percentage of hot metal, and because of this it has been possible to retain the relatively simple three-bay construction of the shop.

The Stockyard Bay

All cold materials for the furnaces enter the stockyard bay in railway wagons or lorries, and are discharged into charging boxes of 35 cu. ft. capacity. A small reserve of scrap and other cold materials is stocked on the floor, and there is sufficient space for a fairly large stock of loaded boxes. These are handled on trays of five which can be stacked three or four high. The two 25 ton cranes, as well as being fitted with magnets, have special sets of hooks with which the driver can engage the trays without the assistance of a slinger.

The stockyard cranes lift the trays of charging boxes on to tables at the back of the furnace charging platform, and they are then handled by 4 ton revolving ground chargers into the furnaces. Dolomite is brought into the shop by road in special containers which are handled by the overhead cranes and discharged on to the stage or into the hopper of the fettling machine.

Hot Metal Transfer

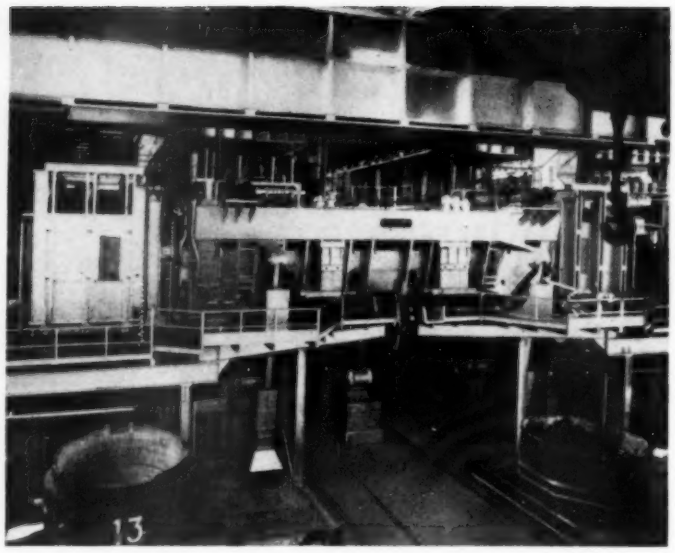
Hot metal is conveyed from the blast furnaces in 50 ton ladles and is poured into the back of the mixer by the 140 ton casting bay cranes. Two 100 ton hot metal

ladle cranes operate in the charging bay. The platform at the front of the mixer is retractable, so that the cranes can lower the 60 ton transfer ladles below the mixer tapping spout. The metal is transferred direct to the furnaces by these cranes.

Mixer and Furnaces

Apart from the bath dimensions, the location of the tapping spout and charging doors, and the arrangement of the rolling gear, the design of the mixer is very similar to that of the furnaces. The bath dimensions of the mixer are 50 × 18 × 6 ft. deep and of the furnaces 45 × 15 × 3 ft. deep.

Port ends are of the dog-house type, with removable slices. The furnaces and the mixer have single B.I.S.R.A. combined coke-oven gas and tar burners at each end, twin air uptakes (7 ft. × 4 ft. 8 in.) and double slag pockets and regenerator chambers. These have been installed so that the furnaces can be converted to mixed gas firing with the minimum amount of alteration. Straight-through air reversing valves are installed and provision has been made in the flue lay-out for the addition of a waste heat boiler at a later date.



One of the three 350-ton tilting open hearth furnaces.

The tilting gear is driven by two 50 h.p. electric motors at each end of the furnace, on the casting bay side, operating through reducing gear boxes to the toothed rack which forms the bottom end of the tilting rams. If one motor fails, it is possible to operate with a single motor driving both units.

The furnaces have five charging doors, with slag notches at Nos. 2 and 4. The slag ladles are mounted in carriages which travel under the furnace to the casting bay, where they are handled by the ladle cranes. The mixer has two charging doors and two fettling doors at the front, and three doors at the rear. Of the latter, either of the outer two can be used for charging hot metal by means of a chute on a rail mounted carriage, and the centre door has a slag notch. The mixer slag ladle is placed in position by the casting bay locomotive.

Instrumentation on the furnaces is quite extensive and includes :—

(1) Coke oven gas flow indicator and recorder.
(2) Tar flow indicator and recorder.
(3) Steam flow indicator and recorder.
(4) Air flow indicator and recorder.
(5) Roof temperature indicator, recorder and alarm.
(6) Furnace pressure indicator and controller.
(7) Stack flue and checker outlet pressure recorders.
(8) Checker-top temperature recorder.
(9) Reversal indicator, measuring the temperature difference in the checker flues.
(10) Tar pressure gauge.
(11) Steam pressure gauge.
(12) Immersion pyrometers for bath temperature measurement.

All reversing valves are operated by push buttons. The pressure of the coke-oven gas in the ring main is 8 lb./sq. in.

The Casting Bay

The furnaces are tapped into 100 ton ladles held by 140 ton ladle cranes, and teeming is carried out through double stoppers into 6½ ton moulds on bogies. Moulds of 12 ton capacity will also be used at a later date.

In addition to their duties in respect of tapping and teeming of heats and ladle repairs, the four 140 ton ladle cranes handle the furnace slag ladles, transferring them between the carriages which run to the slag bank and those under the furnaces. They also empty the blast furnace iron ladles into the mixer.

Ladle repair stands, coke oven gas ladle driers and a stopper drying oven are installed in the casting bay.

Stripping

At a later date a separate stripping and mould preparation bay will be built between the melting shop and the soaking pits, but in the meantime these functions are being carried out in the soaking pit bay. This contains two stripping cranes, two vertical ingot chargers and 14 bottom fired pits, all constructed by The Wellman Smith Owen Engineering Corporation, Ltd. Construction of a further six top fired soaking pits is expected to start shortly.

The mixer and the first of the open hearth furnaces went into operation at the end of June, 1958 and by December all three furnaces were working.

Sierra Leone Iron Ore

HAVING studied the results of a two-year geological examination of iron ore deposits at Tonkolili, the Sierra Leone Development Co., Ltd., is now of the opinion that the project should be proceeded with provided the necessary finance can be obtained. Reporting this from Freetown, Barclays Bank D.C.O. says the most recent estimate shows that the scheme will cost over £20,000,000. The geological examination, which began in 1956, has largely confirmed the company's original views about the size and quality of the iron ore deposits. Much valuable additional information has also been obtained particularly relating to the physical characteristics of the ore.

Investigations on "Active Iron"

Part I—Isolation

By G. V. L. N. Murty, M.Sc., D.Sc., F.R.I.C., F.A.Sc.

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Following the observation that iron deposited electrolytically under certain conditions appears to have an unusually high chemical reactivity, the author reviews previous work on iron-water reactions and sets out the electrolytic conditions for depositing "active iron."

IN the course of our studies on non-metallic inclusions in steel, we carried out a large number of experiments on their isolation after anodic dissolution of the base metal. For this purpose, several sets of conditions were investigated with varying degrees of success. Satisfactory anodic dissolution was effected by using an electrolytic bath consisting of ferrous sulphate in the presence of sodium citrate and sodium chloride. When electrolysis was carried out with an iron rod as anode, a platinum foil as cathode and a current density of 4 amp./sq. dm., it was observed that gas evolution continued at the cathode even after the current was cut off. It was at first thought that the simple process of adsorption of hydrogen by the freshly deposited iron and its subsequent desorption might be responsible for the observed effect, but this view had to be given up in the light of further studies referred to later. These observations suggested the possibility that the iron deposited showed an unusually high chemical reactivity.

Previous Work

The main features of the various papers that have appeared from time to time on iron-water reactions may be summarised as follows :—

Wanklyn and Carrius[1] reported that iron did not react with water at 50° C., whilst finely divided iron obtained by reduction with hydrogen slowly decomposed boiling water, according to Ramann[2]. Friend[3] stated that water and iron could be kept indefinitely in contact with each other in the absence of carbon dioxide and air, and based his acid theory of corrosion on this observation. Schikorr[4] found that the hydrogen evolved at 20° C. in a closed system, by the action of water on iron containing 0·18% carbon and notable amounts of other impurities, generated a pressure of only 5·8 atmospheres after 236 days. The action of pure water on iron at room temperature was studied by Corey and Finnegan[5], who identified the end product as Fe_3O_4 and recorded the presence of 0·3 p.p.m. of ferrous iron in the water. Since the experiment was conducted in an atmosphere of hydrogen, these authors seem to have made no attempt to measure the volume of gas evolved.

An iron deposit readily dissolving in normal hydrochloric acid was claimed to have been obtained by Wrangler[6] by the electrolysis of a solution containing 15 g. of iron as ferrous chloride, 100 g. of ammonium chloride and 5 ml. of acetic acid, at a *p*H of 6·5 and a temperature of 50° C. This seems to be only a case of isolating iron in a form which showed increased reactivity with hydrochloric acid, as compared with the more familiar forms of the metal.

Even the pyrophoric forms of iron, usually prepared by the reduction of the oxides in an atmosphere of hydrogen at high temperatures,[7] or by the electrolysis of solutions of ferrous sulphate and magnesium chloride in glycerol[8], which exhibit spontaneous and violent reactivity in air or oxygen, are very slow in regard to their reaction with water at ordinary temperatures, as reported long ago by Troost and Hantefemille[9] and duly confirmed by us. Against this background, our present observations seem to be rather unique, and systematic studies have, therefore, been undertaken concerning the isolation and reactivity of the new form of iron, which constitute the subject matter of this and the succeeding parts of the series.

General considerations regarding the deposition of metals from their solutions clearly show that those which are higher than hydrogen in the electromotive series and exhibit at the same time low hydrogen overvoltage can be satisfactorily deposited only under nearly neutral conditions. Even though iron belongs to this category, it has been general practice to deposit it from solutions of low *p*H, in view of the obvious difficulties in maintaining high concentrations of iron in baths at nearly neutral conditions. This difficulty was, however, overcome by employing fairly high concentrations of sodium citrate in the bath. The choice of sodium citrate was prompted by its capacity to form complex ions with iron, thereby preventing the precipitation of the hydroxide. Further, it can also effectively serve the very desirable purpose of maintaining the *p*H constant. It is indeed desirable to work with fairly high concentrations of ferrous salts, to offset the depletion of metal ions by complex formation.

Generally, high current density increases the rate of metal deposition. Owing to the reactivity of the active metal with the electrolyte, it is essential that the current density should be maintained sufficiently high. The reverse reaction can further be minimised by keeping the bath at a fairly low temperature, taking care to avoid too much cooling, when separation of the dissolved salts may occur. The requisite high conductivity of the bath can, however, be obtained by addition of suitable quantities of sodium chloride.

Experimental Procedure

Based on the foregoing general considerations, a number of bath compositions were studied, under varying conditions of electrolysis, with a view to arriving

at the most satisfactory procedure for the deposition of "active iron." Our final conclusion in this respect may be summarised as :—

Bath Composition	
Sodium citrate	100–150 g.
Citric Acid	10–20 g.
Ferrous Sulphate ($FeSO_4$ 7 H_2O)	200–250 g.
Sodium Chloride	10–15 g.
Made up to 1 litre with water.	
Hydrogen Ion Concentration	*p*H 4–6
Electrolysis Conditions	
Current density	10–12 amp./sq. dm. at 8–10 volts.
Temperature	20–25°C.
Electrodes	
Anode	Armco iron or mild steel rod or sheet.
Cathode	Strips of any of the following metals: platinum, aluminium, copper, iron, nickel or tin.

Using a platinum strip with a surface area of about 12·5 sq. cm., a deposit of almost 1 g. of the active metal was obtained after 30 minutes electrolysis. The active iron, if exposed to air and moisture, lost its capacity to react with water rapidly. It could, however, be preserved for a few hours if kept in a vacuum over phosphorus pentoxide or magnesium perchlorate. Even under these conditions it showed only slight reaction with water after 24 hours.

The composition of the deposited iron depended on that of the anode used, carbon being the chief impurity. It was found impossible to avoid contamination by it, even by the use of spectrographic quality anodes. The carbon content ranged from 0·6 to 1·7%, depending on whether pure iron or mild steel anodes were used. Such carbon pick-up by electrolytic iron from baths containing small quantities of organic impurities has been observed before[10]: in the present case it seems to have been caused by the electrolytic decomposition of the citrate. In samples of deposit obtained with a mild steel anode, no silicon or manganese could be detected, even spectrographically. Sulphur was, however, present to the extent of 0·02%.

For the purpose of systematic investigation of the reactivity of this active form of iron, it has been necessary to devise both new experimental techniques for the measurement of the quantity of hydrogen evolved under different conditions, and methods for the rapid determination of iron in the presence of large amounts of sodium citrate. These will be dealt with in a later paper, followed by particulars of the reactivity of the metal.

Acknowledgments

The authors' thanks are due to the management of The Tata Iron and Steel Co., Ltd., for permitting publication of this paper.

REFERENCES

1 Wanklyn, J. A. and Carrius, L., *Liebig's Ann* 1861, **120**, 69.
2 Ramann, E., *Ber*, 1881, **14**, 1433.
3 Friend, J. N., *Engineering*, 1910, **88**, 526.
4 Schikorr, G., *Zeit. Electrochem.*, 1929, **35**, 62–65.
5 Corey, R. C., and Finnegan, T. J.: *Proc. A.S.T.M.*, 1939, **39**, 1242–1260.
6 Wrangler, G., *Svensk. Kem. Tid.*, 1949., **61**, 246–252.
7 Mellor, J. W., "Comprehensive Treatise on Inorganic and Theoretical Chemistry." Vol XIII p. 311 (Longmans & Co., 1934.)
8 Kremann, R. and Lorber, J. *Monatsh.* 1914, **35**, 1387–1422.
9 Troost, L. and Hautefeuille, P. H., *Compt. Rend*, 1873, **76**, 562.
10 Per. Frocheck, K. *Trans Amer. Electrochem. Soc.*, 1924, **46** (reprint).

Tonnage Oxygen for Gas Making

BRITISH OXYGEN LINDE, LTD., has been awarded a contract for a tonnage oxygen plant worth nearly £750,000. The contract was placed by Humphreys and Glasgow, Ltd., who are building Britain's first Lurgi pressure gasification plant for production of town's gas at Westfield, Fifeshire, for the Scottish Gas Board. The Westfield project will use oxygen and superheated steam for the complete gasification of low grade coal which is unsuitable for normal gas making processes. The oxygen plant, will be capable of producing 200 tons of oxygen per day and is scheduled to go into production during the latter half of 1960.

"O.L.P." Process of Steelmaking

THE new oxygen process of steelmaking by the O.L.P. (oxygen, lime-powder) method, as developed by the French iron and steel research institute, IRSID, is now in current use as a successful commercial process by the Denain works of the USINOR steel company. This works has already satisfactorily produced over 10,000 tons of steel by this technique, and the steel is readily accepted by consumers as a grade equivalent to high-grade open-hearth steel. Extensions to the USINOR equipment are in hand to increase production by this method.

IRSID were the first to produce steel by blowing molten pig-iron with lime-powder in suspension in pure oxygen, after years of study, and were also first to publish the results. The December 1958 issue of *Revue de Metallurgie* (France) contains an article on the subject, giving complementary information to earlier papers presented in October 1957 and 1958 in Paris February 1958 in New York and June 1958 in Liege. A series of patents on this process has been filed in France and other countries.

On account of the flexibility of adapting this process to pig irons of widely different compositions, several French and foreign steel companies are showing keen interest in the O.L.P. process, which promises to become a very important development in steelmaking.

Correction

METAL SPRAYING: EFFECT OF A MOLYBDENUM DEPOSIT ON ADHESION AND ON FATIGUE OF FERRITIC STEELS

We regret the following errors which appeared in the above article in our December issue :—

In the smaller type in the first column of p. 274, the shot is described as B.S.S. 251 grade 18; this should read, B.S.S. 2451 grade 18.

The footnote to the second column of p. 274 reads, "Sprabond wire was used: this is the registered trademark of the Metallizing Equipment Co., Inc., New York." The correct wording is "Spraybond Wire was used; this is the registered trademark of Metallizing Engineering Co., Inc., New York." This correction also applies to the footnote to Table II. In this country Metallizing Equipment Co., Ltd., of Chobham, Woking, are registered users of the mark. The latter company have drawn our attention to the fact that there is in existence British Patent 692,185 covering certain aspects of molybdenum spraying for adhesion purposes.

Regenerators and Preheat Temperatures

IN 1956 the Steelmaking Instruments Sub-committee of the British Iron and Steel Research Association examined the available information on regenerators for open-hearth furnaces, but could find nothing that could be applied in practice to increase preheat temperatures. As a result, a Regenerator Group was formed in January 1957 to ' summarize the present knowledge of regenerator theory and practice, indicate what further gains in furnace performance might be achieved by improvements in regenerator efficiency, and recommend the course further investigations should take'. The Group has begun its work by preparing a report* which contains a critical survey of experimental work on open-hearth regenerators, a review of theoretical and experimental work on heat transfer, and a recommended method of calculating heat transfer in a regenerator.

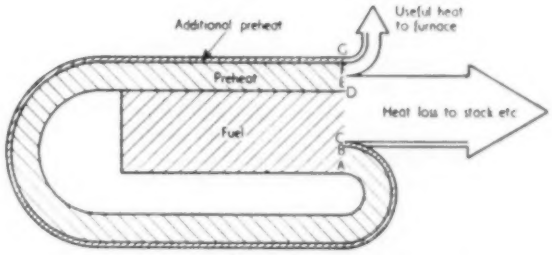
Part I of the report reviews experimental work on regenerators. However high the rate of heat transfer, the waste gases will never leave the bath at a temperature much lower than that of the surface of the slag. The burning gases can thus give up only a relatively small fraction of their heat while they are actually in the furnace. For this reason, the principle of regeneration becomes more important the lower the grade of the fuel and the higher the surface temperature of the charge.

The amount of heat returned to the furnace is determined by how nearly the preheat temperature can approach the waste-gas temperature (other conditions remaining constant). However, measurements reported by several investigators indicate that, during the refining period at least, waste-gas temperatures are surprisingly constant within the range 1,600–1,650° C. Even enrichment of the combustion air with 30% of oxygen makes little difference.

Raising the preheat temperature increases the amount of heat released in the furnace and thus improves its performance. The diagram shows how an increase in the preheat temperature increases the " useful heat ", i.e. the amount of heat available before the gases are cooled to the temperature of the steel in the bath. The quantity of heat in the gases leaving the furnace at (say) 1,600° C. depends on the fuel and the amount of air infiltration that takes place, but is independent of the preheat temperature. If the amount of heat re-circulated as preheated air is increased from AB to AC, the total heat will be increased from AF to AG; the additional useful heat re-circulated will then be in the proportion $FG : EF$ rather than $FG : AD$.

The available evidence indicates that increasing the preheat temperature by 100° C. will increase the working rate of the furnace by from 5 to 10%, and will reduce the fuel consumption by a similar amount. These estimates emphasise the importance of analysing waste gases as a check on infiltration of air into the furnace, and of measuring not only preheat temperatures but waste-gas temperatures as well.

The efficiency of checkers has been the subject of many investigations. It is well known that the flow of gases through the regenerator is usually far from uniform; little evidence is, however, available on the effect on preheat temperatures of divergences from the ideal flow-pattern. The distribution of gases in a regenerator is sensitive to the conditions at the inlet, and simple modifications at this point which promote a smooth entry into the chamber may have a considerable effect on the gas-flow.



All heat derived from increased efficiency of regenerators is available as useful heat in the furnace.

The part played by the uptakes and slag-pockets in regeneration has been studied in recent years, and it has been shown that the additional regenerative effect can be related to the ratio between the heating surface of the uptake and slag-pocket and their volume. Further research on this aspect might well be profitable; one difficulty is to decide on the effective area of the heating surfaces of the uptake and slag-pocket.

Infiltration of air can affect preheat temperatures by as much as 250–300° C. For the first few heats after relining, air infiltration is typically about 25%; it may subsequently decrease to 20% or less, but will then rise again gradually and will approach 25% near the end of the campaign.

The preheat temperature tends to fall as deposits accumulate in the regenerators, and a marked drop in preheat is not unusual during a campaign. This can be reduced by cleaning the regenerators at regular intervals. An advantage can be gained here by using horizontal regenerators, for they are much easier to clean than the normal type. Periodical cleaning also makes it possible to use checkers with smaller openings, which will provide a higher preheat temperature.

Parts II and III of the report give details of methods of calculating preheat temperatures for regenerators, illustrated by a worked example. Using the recommended method the heat transfer in a regenerator can be worked out in about half an hour. The calculation is straightforward. Charts and graphs are also provided in the report so that the effects of changes in design can be obtained without the need for a complete calculation.

Atomic Information Available

THE United Kingdom Atomic Energy Authority has been considering the question of the distribution of abstracts of unclassified material, and it has been decided that for convenience they will in future be supplied on 5 × 3 in. cards instead of typewritten sheets. This should provide an easier means of reference.

* ' Open-Hearth Furnace Regenerators: a Survey of Theoretical and Experimental Work with Recommendations for the Calculation of Preheat,' (SM/AH/103/58) by the B.I.S.R.A. Regenerator Group. *Journal of the Iron and Steel Institute*, **191**, November 1958, 254. Copies of this report are available from the Information Officer, B.I.S.R.A., 11, Park Lane, London, W.1.

A Guide to ACE

N.P.L.'s New Electronic Computing Machine

ONE of the world's largest and fastest electronic computing machines—popularly called "electronic brains"—has begun to operate at the National Physical Laboratory. Its name is ACE—and it can carry out any calculation process for which exact rules are known. Very fast computers of this type are required for many problems, of which design calculations for high-speed aircraft and nuclear reactors are typical examples. The emphasis in the N.P.L.'s use of ACE will, however, be into the general methods by which computations such as these can be carried out.

ACE is the end-product of research which began at the National Physical Laboratory at the end of the war. In 1945, the late Dr. A. M. Turing, F.R.S., joined the staff of the Mathematics Division at N.P.L. and in the early post-war years he produced, with his collaborators, a logical design for a computer intended to carry some of the load of numerical calculation. He called it the Automatic Computing Engine—or ACE. In 1947, a special section—now the Control Mechanisms and Electronics Division—was set-up to carry out the development of the machine. It was, however, thought unwise to attempt to build so large and complex a machine in one step—so it was decided to make first a pilot model of considerably smaller power and capacity.

The Pilot Model

Thus, a pilot-model ACE, only one-sixth of the size of the present machine, was built to investigate the engineering problems which would arise in the full-scale machine. It was completed in 1951 and during its five-year life at N.P.L.—it was presented to the Science Museum in 1956—it carried out a considerable amount of work, including extensive calculations to discover the cause of failure in the early Comet. It was, in fact, the pilot-model which led to the commercial production of the English Electric DEUCE computer. Moreover, it provided the team of mathematicians, logical designers, electronic engineers and mechanical engineers with the essential experience and "know-how" to undertake the more ambitious full-scale ACE project.

The numbers and instructions have 48 binary digits (equivalent to 14 decimal digits). The working store consists of 800 words, and the backing store of four magnetic drums will contain a total of 32,768 words. Mercury delay lines and magnetic drums (the working and backing stores respectively) are used for the storage of numerical data and instruction sequences, and both punched card and magnetic tape equipment are provided for input and output.

The Control Desk

The compact control desk has some 160 keys and 300 signal lamps, in addition to audible and visual displays of the computation. Nevertheless, most computations are carried out entirely by pushing one key—marked "Initial Input." This key causes punched cards to be read, which tell ACE what to do.

The most interesting mechanical assemblies in ACE are the four magnetic drums, entirely designed and constructed at N.P.L. The drums rotate at 12,000 r.p.m. so accurately that the arrival at a given point of a magnetic spot one hundredth of an inch in length, travelling at 200 m.p.h., is timed to a millionth of a second. The drums have unique rapidly moving recording heads, and are only a part of the number store or "memory" of ACE. An idea of the speed of ACE can be gained from the fact that these drums are the slowest part of its number store!

ACE incorporates many unique design features. The operating "mechanism" consists of about 6,000 miniature electronic valves arranged in an impressive array of ten large cabinets. Each cabinet is fitted with an electrically operated rising door to give rapid access for fault finding. It has a cooling system of circulating air, with heat exchangers and a water cooler.

Forms of Storage

ACE has three forms of storage. The largest part of the store consists of four magnetic drums. These rotate at 12,000 r.p.m., and store a total of 32,768 numbers. The access to these numbers is limited by the need to wait for the drum to revolve, and may take up to 7 milliseconds (0·007 sec.). These drums are used by the computer for the large mass of data that it may not want quickly. For more rapid access, a mercury delay line store of 768 numbers is employed. The time required for access to these is up to a thousandth of a second. This store is used for the program, but instructions are stored in such a way that no time is wasted in waiting for them. The most rapid access store consists of short delay lines storing one, two or four numbers each. These are used for the small group of numbers that the computer is using for a short while. By good programming, the full advantages of the large store can be enjoyed, with a time of access not much greater than is given by the short delay lines.

The ACE instructions specify the addresses—the locations in the store—of two numbers to be operated on, the operation, and the addresses of the desired destination of the result and the location of the next instruction. Thus four addresses are used, and all four accesses occur nearly simultaneously. In addition, multiplication and division occur in separate, autonomous devices, so that they can occur simultaneously with other operations.

In many cases, the computer will average 15,000 operations per second, each involving the extraction of two operands (numbers to be operated on), storing the result and extracting the next instruction. Input and output is by punched cards. Magnetic tapes will be fitted later, but will be used as an extension to the store. The input speed from cards will be 7,000 binary digits per second, with a rate of 450 cards per minute punched in binary.

THE address of British Insulated Callender's Cables, Ltd., branch office at Derby is now: Hartington Street, Derby. The telephone number remains the same, Derby 41421.

NEWS AND ANNOUNCEMENTS

Mond Nickel Fellowships

THE Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for 1959. The main object of these Fellowships is to enable selected applicants of British nationality, and educated to University degree or equivalent standard, to obtain additional training and wider experience in industrial establishments, at home or abroad, so that, if they are subsequently employed in executive or administrative positions in the British metallurgical industries, they will be better qualified to appreciate the technological significance of research and to apply its results.

There are no age limits, though awards will seldom be made to persons over 35 years of age. Each Fellowship will occupy one full working year. It is hoped to award five Fellowships each year of an approximate value of £900 to £1,200 each. Applicants will be required to define the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications and previous career. Full particulars and forms of application can be obtained from: The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the Committee not later than the 1st June, 1959.

Waverley Gold Medal Essay Competition

FOR the seventh year in succession, the journal *Research* is sponsoring the Waverley Gold Medal Essay Competition, which aims at encouraging and promoting improved and more effective reports of scientific and technical work. The Waverley Gold Medal and a prize of £100 will be awarded for the best essay of about 3,000 words describing a new scientific project or practical development giving an outline of the scientific background, the experimental results, and the potential application of the project or process in industry. A second prize of £50 will be awarded, and also a special prize of £50 for the best entry from a competitor under the age of thirty on the closing date, July 31st 1959. Further particulars can be obtained from The Editor of *Research*, 4/5 Bell Yard, London, W.C.2.

Indian Aluminium Smelter Opened

A SIGNIFICANT milestone in India's industrial growth was achieved last month with the inauguration by Indian Aluminium Co., Ltd., of a new aluminium smelter which more than doubles India's capacity for the production of primary aluminium. Dr. Harekrushna Mahtab, Chief Minister of the State of Orissa, officiated at the opening ceremony of the smelter, which has an annual capacity of 11,200 tons of aluminium per annum. Aluminium, Ltd., has a 61% interest in the Indian company and the remainder is held by approximately 3,000 Indian shareholders. Built at a capital cost of $10m., the smelter forms a part of a $30m. integrated expansion project involving bauxite, alumina, metal production and fabrication.

The establishment of smelting capacity at Hirakud is based on the supply of electric power from the State-owned 165,000 h.p. Hirakud generating plant, and an expansion of the existing bauxite and alumina production facilities in Bihar State. The Indian company has under consideration plans to expand the Hirakud smelter to 22,400 tons capacity, and discussions are currently taking place with the Orissa Government for the supply of the additional power required. The Hirakud hydro-electric project on the Mahanadi River is one of the major new developments in India, involving a dam three miles long and providing flood control and irrigation as well as power for industrial growth.

Partial expansion of the bauxite-alumina facilities has been completed, and further expansion would be undertaken concurrently with the smelter expansion to meet the full requirements of the Hirakud smelter, as well as the company's older 6,500 tons capacity smelter in Kerala State. The Indian Aluminium Company was established in 1938 and has been for several years a fully-integrated enterprise with substantial fabricating facilities in Calcutta, Bombay and Kerala State.

Atomic Information Available

IN order to make atomic information more easily available, the U.K. Atomic Energy Authority has decided to make fuller use of microphotography. The effect of this will be to make all non-secret reports which have been prepared since 1947 readily obtainable. Complete sets are also being presented to a number of other countries and to certain international agencies.

In addition to this, the Authority is increasing its facilities for supplying reports in conventional form as they are prepared. The details of the methods now introduced are:

(*a*) From February 16th, 1959, a large number of unclassified and declassified reports, which have hitherto been obtainable only on loan from A.E.A. libraries, will be available in micro form. Arrangements have been made with Micro Methods, Ltd., of East Ardsley, Wakefield, Yorks., for the production of microcopies on card of all unclassified and declassified reports issued between 1947 and December, 1956, and, on a continuing basis, of those reports issued since 1956 which are not available on sale from Her Majesty's Stationery Office. Microcopies may be purchased from Micro Methods, Ltd., as follows:

(1) All unclassified and declassified reports issued between 1947 and 1956. Complete set . . . £120. The Atomic Energy Authority is presenting complete sets of these microcopies to those overseas countries with which the Authority has active report exchanges. Sets are also being presented to the International Atomic Energy Agency, the European Nuclear Energy Agency and Euratom.

(2) Unclassified and declassified reports (except reports for sale) issued January, 1957 to June, 1958. Complete set . . . £14.

(3) Unclassified and declassified reports (except reports for sale) issued July, 1958 to June, 1959. Complete set . . . £9.

Individual reports may also be purchased separately

at a cost of 2s. per card. A list of all reports of which micro-copies are available may be obtained from Micro Methods, Ltd., at the address given above.

(*b*) Paper copies of all currently issued unclassified A.E.A. reports may now be obtained against a running account from the Library, Atomic Energy Research Establishment, Harwell, Didcot, Berks. Bills will be sent quarterly covering reports despatched in the previous quarter. Subscribers may order all reports issued or those in any of the following categories: biology and medicine; chemistry—general; chemistry—radiation and radiochemistry; chemistry—separation processes for plutonium and uranium; controlled thermonuclear processes; criticality studies; geology and mineralogy; health and safety; instruments; metallurgy and ceramics; particle accelerators and high-voltage machines; physics and mathematics; radiation effects on materials; radioactive waste; reactors—general; reactors—power; stable isotope separation; technology—feed materials; and technology—raw materials.

Ergonomics in Industry

THE Ergonomics Research Society is holding a conference on this theme at Balliol College, Oxford, from April 6th to 9th next, under the chairmanship of Sir David Lindsay Keir, Master of Balliol, Mr. Ernest Marples, M.P., the Postmaster General, being the guest of honour at the opening reception. More than twenty papers will be delivered during the course of the conference by workers in the ergonomics sphere in Britain, Germany, Holland, the U.S.A., France, and Sweden. The overall themes for the three operative days of the conference are 'Ergonomics Research Since 1948' (Tuesday April 7th), 'Laboratory and Industrial Studies and Application' (Wednesday), and 'Future Trends and Needs in Ergonomics Research' (Thursday).

The Ergonomics Research Society was founded in 1949 to bring together scientists engaged in different fields, but with a common interest in problems of human efficiency at work. In the ten years of its existence the Society has become international in scope, reflecting the growing attention which is being directed to the subject. Industry in particular is showing increasing interest in this relatively new science, with its direct impact on industrial sociology and economics. The conference will provide a valuable opportunity for surveying past progress and future trends in the science. Full particulars regarding the programme, accommodation, etc., can be obtained from the conference secretary, Dr. S. Griew, Department of Psychology, 22 Berkeley Square, Bristol 8.

D.S.I.R. Long-Term Researches Grants

LONGER-TERM grants for special researches will be awarded by the Department of Scientific & Industrial Research in future. These grants—which have normally been limited to a maximum of five years—may now be awarded for an initial period of up to seven years with the possibility of continuing support for a further ten years. This change in policy has been made to meet present day needs. The more complex and expensive researches may require support for more than five years to become fully established. When fully established the support for these researches will be transferred from D.S.I.R. to the university; arrangements are being worked out to simplify such transfer. The Department is therefore willing to support for longer periods outstanding university investigators embarking on promising researches for which their universities are unable to make adequate provision. The main conditions are:

An initial award for periods of three to seven years with the possibility of two renewals, each of a maximum duration of five years. A third renewal would not normally be given.

Details of the scheme are contained in the 1959 edition of "Notes on D.S.I.R. Grants," published by H.M.S.O. in January.

International Congress on Electro-Heat

THE fourth International Congress on Electro-Heat is to be held at Stresa, Italy, from May 25th to 29th. Some two hundred papers will be presented to the ten sections into which the Congress will be divided, and these will include nineteen by British authors.

Included in the British contribution will be papers dealing with various aspects of arc, induction and resistance furnaces for heating solid metal and for melting; vacuum furnace technology; and the development of electric smelting in the British Commonwealth.

Exhibition of Electronic Instruments

MORE than four hundred instruments will be displayed at the Third Annual Exhibition of electronic devices organised by the Midland Sales Service Division of A. M. Lock & Co., Ltd. The exhibition will be held in the Bennett Hall, Y.M.C.A., Sun Hill, Birmingham, 4, from March 17th to 20th, 1959. The exhibitors will include W. G. Pye & Co., Ltd., Elcontrol, Ltd., Cosser Instruments, Ltd., Sodeco Counters, A. M. Lock & Co., Ltd., Southern Instruments, Ltd., Loma Metal Detectors Ltd., and Thomas Industrial Automation. Tickets of admission may be obtained from A. M. Lock & Co., Ltd., Midland Sales and Service Division, Newborough House, Newborough Road, Shirley, Solihull, Warwickshire.

E.S.C. Magnet Subsidiary

THE permanent magnet business previously carried on by English Steel Rolling Mills Corporation, Ltd., has been transferred to English Steel Magnet Corporation, Ltd., North Street Works, Openshaw, Manchester, which is a newly-formed wholly-owned subsidiary of the parent company, English Steel Corporation, Ltd., Sheffield. Plant for the production of permanent magnets, including well equipped machining, heat treating and testing departments, has now been concentrated under one roof, and the completion of this scheme provides a good opportunity for introducing unified control and administration. It is with this object in view that a new company has been formed. Chairman of the Magnet Corporation is Mr. R. G. H. Taylor, and Mr. E. J. C. Patrick, formerly Manager of the Tool Steel Department, has been appointed Director and General Manager. Mr. F. S. Beale and Mr. P. Turrell have also been appointed Directors, and the new Corporation's Secretary is Mr. A. M. Simmers.

High Duty Alloys, Ltd.

HIGH DUTY ALLOYS, LTD., announce that a new Midland Area Sales Office has been opened at Queen's College Chambers, 38a Paradise Street, Birmingham, 1 (Telephone: Midland 3286) to handle sales of Hiduminium

sheet, extrusions, tube and castings, for the convenience of customers in that area.

A second change is also announced. All home market enquiries and quotations in regard to forgings will be handled from a new Sales Department situated at the Forging Division of High Duty Alloys Ltd., Windsor Road, Redditch (Telephone : Redditch 711). Mr. G. F. Ingram has been appointed Sales Manager and he will be supported by Mr. F. Clark as Sales Office Manager.

Personal News

IT is announced that Cooke, Troughton & Simms, Ltd., a company of the Vickers group, has purchased all the issued capital of C. Baker of Holborn, Ltd., an old-established business of optical instrument makers with a works at Purley Way, Croydon. The Board of Directors has been reconstituted and is now as follows : MR. P. D. SCOTT MAXWELL, D.S.C., (Chairman), MR. M. G. L. CURTISS (Managing Director), MR. E. E. KENNAIRD, and MR. H. WRIGHT. The Secretary is MR. J. WILLIAMSON and the Registered Office will be moved to Vickers House. The name of the company will be changed in due course to C. Baker Instruments, Ltd.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announces the appointment of MR. H. WEST, as Assistant Managing Director, in consequence of which, Mr. West ceases to act as Director of Electrical Engineering.

MR. C. E. WALTERS has been appointed General Sales Manager covering all the products of Sunvic Controls, Ltd., whilst retaining responsibility for the Domestic Products Division. Sales Managers of other Divisions are : MR. R. LLOYD, Scientific and Industrial Products ; MR. J. M. ANDERSON, Pneumatic Instruments; and MR. W. J. DONNELLY, Data Processing ; MR. E. C. BIRD is Manager of the Contracts Section.

SIR W. H. BAILEY & CO., LTD., (Albion Works, Patricroft, Manchester), announce that MR. S. WATTS, Chief Draughtsman has been appointed Chief Engineer (Contracts Division) and that MR. B. SCOTT-GARRETT has joined the company as Chief Engineer (Control Division).

MR. S. P. MAYNARD has been appointed Technical Adviser on the steel industry to Brookhirst Igranic, Ltd.

MR. K. WALKINGTON, Sales Manager of the Foundry and Engineering Division of Armstrong Whitworth (Metal Industries), Ltd., is at present on an overseas tour which includes visits to Africa, India, Hong Kong, Singapore, Australia, and New Zealand. The purpose of the tour is to investigate the export sales position regarding the company's crushing plant (including Kue-Ken stone crushers, screens, etc.), castings and general engineering products.

AFTER nearly 47 years service with the British Thomson-Houston, Co., Ltd., MR. C. H. CHAPLAIN, Manager of Publicity Department, has retired. He is succeeded by MR. H. G. HARLOW, who has been Manager of the B.T.H. Newcastle District Office since May 1955.

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announces the appointment of MR. G. R. HIGGS as Chief Engineer, Traction Projects Department ; this appointment will enable MR. F. WHYMAN, who relinquishes the position, to devote his full time to his duties as Chief Engineer, Traction Division. MR. J. BEASLEY is appointed Assistant Chief Engineer, Traction Control Department, in succession to MR. A. D. FERGUSON, who is appointed Consulting Engineer, Traction Control Department. MR. J. L. RUSSELL, is appointed Chief Engineer, Railway Signals Department ; responsibility for this department is relinquished by MR. W. T. GRAY, Chief Engineer, Traction Control Department.

MR. J. H. OSBORN, a Director of Samuel Osborn & Co., Ltd., Sheffield, and General Manager of Osborn Precision Castings, Ltd., has been chosen as prospective Conservative and Liberal Parliamentary Candidate for Hallam Division of Sheffield.

MR. J. F. HANCOCK has been appointed Assistant Superintendent, Maintenance Department at Metropolitan-Vickers Electrical Co., Ltd.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce that SIR JOHN DEAN, has been appointed a Director of the company.

MR. P. G. SMYRK, hitherto Manager of the Export Division of the company, and a Director of several of its overseas subsidiaries, has been appointed a Joint Managing Director of Johnson, Matthey & Co., Ltd.

MR. W. F. CARTWRIGHT, D.L., J.P., Assistant Managing Director of The Steel Company of Wales, Ltd., has been appointed a Director of Davy and United Engineering Co., Ltd.

OWING to the continued expansion of the Foundry Services Group, MR. E. WEISS has relinquished his position as Managing Director of Foundry Services, Ltd., in order that he may be able to give more time to directing the parent company, Foundry Services International, Ltd., DR. D. V. ATTERTON has been appointed Managing Director of Foundry Services, Ltd.

MR. R. E. WILSON, Managing Director of Fescol, Ltd., retired at the end of January. He is succeeded by MR. F. B. STRACHAN, who has been Assistant Managing Director since 1951. Under consequent staff changes, MR. W. A. LESLIE continues as Director and Sales Manager ; MR. F. BADEN is appointed Works Manager in London, and MR. C. W. HAY succeeds him at Port Glasgow. MR. A. E. LOCKLEY is appointed Works Manager in Huddersfield, and MR. R. F. BURKE becomes Works Manager of the Midlands plant.

THE HON. J. K. WEIR, C.B.E., Chairman of G. & J. Weir Holdings, Ltd., and G. & J. Weir, Ltd., of Glasgow, has been elected a Director of The International Nickel Company of Canada, Ltd., and a member of its Advisory Committee. He fills the vacancy on the International Nickel Board left by the retirement of his father, THE RT. HON. VISCOUNT WEIR, P.C., G.C.B., who had served as a Director since 1928.

MR. W. L. VALENTA has been appointed Sales Development Engineer of Workington Iron and Steel Co., a Branch of The United Steel Cos., Ltd. Mr. Valenta, who was formerly Production Research Engineer, will now be responsible to the company's Commercial Manager.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce that MR. C. S. F. LANE has been appointed to the position of Regional Manager for Australia and New Zealand in the Overseas Organization in London. He succeeds MR. R. H. SEMPLE, who has taken up a senior executive post with an associate company in Australia.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Electronic-Pneumatic Level Controller

THE FIELDEN on/off Pneutronic level controller has been designed to control the level of any liquid or granular solid where the valve or other regulating device is, or can be, air operated. The capacitance to earth of a vertical electrode mounted in the container varies with the level of the material, due to the difference in dielectric constant between the material and air. This capacitance is used in an oscillator circuit, and the level at which the circuit oscillates is fixed by the setting of a variable condenser. When oscillation occurs, a D.C. signal is fed to the converter, which consists of a small electrically operated shuttle valve, which then allows air to pass to the control valve or reduces the control valve air pressure to atmospheric, depending upon whether the instrument is arranged as a direct acting or reverse acting controller. When the material falls below the desired level, the D.C. signal is removed from the shuttle valve and the output air pressure reversed.

The Pneutronic on/off level controller can be used for the control of powdered or granular solids, or any liquid. The electrode must be chosen to suit the particular application, but can be supplied for use at high temperature, at high pressure, or in corrosive conditions.

Fielden Electronics, Ltd., Wythenshawe, Manchester.

Radiation Pyrometer for Liquid Iron and Steel

A NEW radiation pyrometer, designed to meet the foundry industry's growing need for closer control of liquid iron and steel temperatures, has just been introduced by Land Pyrometers, Ltd. Known as the R.P.18, it can be used to measure the temperature of the metal as it leaves the cupola or holding furnace with an accuracy comparable to that of an immersion pyrometer.

By using a photocell instead of a thermopile, the manufacturers claim to have successfully eliminated the serious effect of metal emissivity on the accuracy of the reading—the main drawback of previous radiation pyrometers introduced for this purpose. Calibration is for the normal emissivity of a liquid metal stream, and the small variations encountered in practice have only a negligible effect on the readings. The R.P.18 can be focused on a target as small as 1 sq. in., and is, therefore, easily sighted on the metal stream in the slag box. The indicator or recorder can be either of the millivoltmeter or potentiometric type, a range of 1,300–1,600° C. being normally suitable.

The pyrometer lens is protected by a window of heat resisting glass, which can easily be cleaned, or replaced, if accidentally splashed with metal. To avoid damaging the photocell, a water jacket is supplied with the new instrument in order to keep its temperature below 40° C. The pyrometer is easily clipped into the jacket with an accurately reproducible alignment. Another integral part of the equipment is the air purge unit, which enables an air jet to be blown down the optical path to keep it free from fumes. This also helps to protect the pyrometer window.

It is claimed that the use of the new pyrometer—a typical installation of which is shown in the illustration—results in improved physical and mechanical properties of castings, fewer misruns, a lower coke rate, and smoother foundry operations in general.

Land Pyrometers, Ltd., 318 Queens Road, Sheffield 2.

Mallory 1,000

JOHNSON MATTHEY AND CO., LTD., announce that they are now producing and marketing Mallory 1,000, a machinable high density material composed of tungsten, nickel and copper, and made by a special powder metallurgy technique. Mallory 1,000 has a uniform structure, high strength and great density. As the material may be subjected to all normal machining and grinding processes, it is ideally suitable for the manufacture of components where high mass coupled with high strength and small volume are important considerations. Components fabricated from Mallory 1,000 are finding increasing application as counterbalances for aircraft control surfaces, balances for flywheels, inertia members in such instruments as accelerometers, and as rotating inertia members, where strong precision-machined rotors are required in a limited space.

A further major application of Mallory 1,000 is in radiation shielding. By virtue of its physical structure and its very high density, Mallory 1,000 effectively absorbs gamma rays, and can also be used for the shielding of neutron-emitting fission by-products, provided that the intensity of bombardment is relatively low. Such low-intensity neutron bombardment causes only moderate activity in Mallory 1,000.

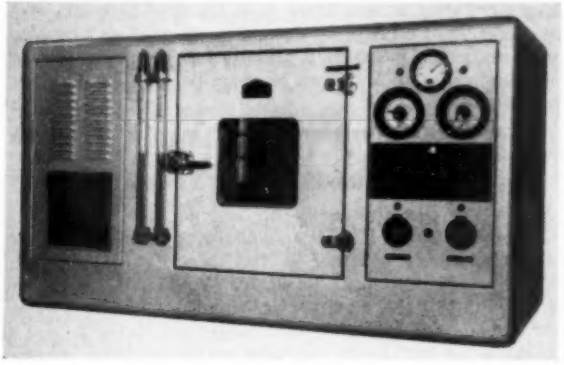
Mallory 1,000 is supplied in special pressed shapes as well as in the form of round and rectangular bars.

Johnson Matthey & Co., Ltd., 73–83, *Hatton Garden, London, E.C.*1.

Humidity Cabinet

THE Hedin standard range of humidity cabinets now includes a model equipped with a refrigeration plant, to enable low temperature testing to be carried out to M.O.S. and other specifications. The unit has a capacity allowing temperatures of — 10° C. to be obtained in an ambient of 20° C. Automatic temperature control is provided by an adjustable thermostat, and the unit is powered by an electrically-driven, hermetically-sealed compressor circulating Freon 12 refrigerant. Refrigeration can also be arranged to provide dehumidification at ambient temperature.

The internal dimensions of Hedin standard humidity cabinets range from 18 × 18 × 18 in. to 36 × 36 × 36 in. Construction is of stainless steel and aluminium, with electroplated brass fittings to eliminate the possibility of rusting. Fibreglass, 2 in. thick, ensures higher thermal stability and efficiency. A practically silent fan unit provides an ample air flow through the humidity chamber, giving a maximum temperature gradient of ± 1° C. throughout the working space. For ease of operation all the controls are mounted on the front of the cabinet. Special attention has been given to facilitating maintenance, and all control gear, wiring and heaters are easily accessible behind removable panels.



Humidity is normally produced by steam injected into the air stream near the fan and thoroughly mixed and cooled before it reaches the humidity chamber. If extended ranges of humidity or temperature are required, a comprehensive set of auxiliary equipment is available, in addition to refrigeration, including water cooling and water spray. Timers can be fitted providing automatic control at pre-determined conditions such as are required by Ministry of Supply specifications.

*Hedin Ltd., Commerce Estate, South Woodford, London, E.*18.

Diamond Polishing Compound for Metallography

THE use of diamond powder in the final polishing of metallurgical microspecimens is finding increasing application for a wide range of metals. Among the advantages claimed for Microfin—a new diamond abrasive compound developed for metallography—is that it does not dry out in lumps, so that polishing cloths can be used for long periods without washing. Furthermore, it does not throw off the wheel, so that considerable saving is achieved compared with the normal type of abrasive. Because of the hardness and sharpness of the diamond particles, the polished surface obtained is flat and free of metal-flow, and the absence of relief between hard and soft constituents in the structure is particularly valuable when photo-micrographs are to be taken. Moreover, first-class preparations can be achieved with little manual effort and with less skill than was formerly necessary.

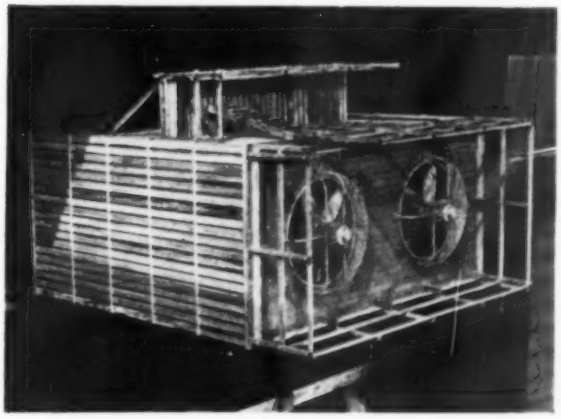
Microfin is a compound of clean, virgin diamond powders accurately graded for the polishing of metallurgical specimens. The powders are compounded into a soft paste with strong properties of adherance: the degree of dilution can be controlled by the addition of Microfin fluid. The compound is available in eight different micron sizes, the mean size ranging from ¼ to 16 microns, and each size is supplied in various diamond powder concentrations. The finer powders are used for the final polishing operations, but some of the coarser ones have proved themselves extremely useful in the preparatory fine grinding stages. For example, the 16 micron size is recommended for fast lapping tungsten carbide, steel and sapphire; the 10 micron size for lapping on tungsten carbide, ceramics and steels, and for the removal of deep scratches; and the 6 micron size as a pre-polish for metallography.

Universal Diamond Co., Ltd., Unidex Works, 192 *Seven Sisters Road, London, N.*4.

Mechanical Cooling Tower

AN important part of modern factory design is the provision of a means of water cooling which is efficient and economical to operate, and which occupies the smallest possible space. A type of cooling plant which combines these requirements, and which is becoming increasingly popular in this country, is the mechanical cooling tower of the induced draught type.

In this type of structure the fans are situated at the top and cause the air to enter the base of the tower at a relatively slow speed and to leave from the top at high velocity. The advantages of this method are that the incoming air is circulated more evenly through the



packing, and that recirculation is not likely to occur. Recirculation is a difficulty which sometimes occurs with mechanical towers of the forced draught type, as in these structures the air is forced into the base of the tower at high velocity, causing a depression into which the saturated vapour emerging relatively slowly from the top is sometimes drawn and recirculated through the tower, thus greatly lowering its cooling efficiency.

Film Cooling Towers (1925), Ltd., have developed a system of packing for induced draught cooling towers which provides the greatest possible degree of heat transference with a low capital outlay. This system, known as film flow, distributes the liquid evenly over the packed area of the tower and gives the cooling air unimpeded access to all parts of the packing.

The water is led to the tower either in a closed pipe or in an open culvert, from which it is discharged into secondary troughs through orifices specially designed to prevent splashing. From the secondary troughs it is fed into weir-type spreader troughs running the entire length or breadth of the tower at a pitch of 6 in. The spreader troughs, which have specially shaped notches at 2 in. or 4 in. intervals, rest on the top layer of the tower filling. The filling is composed of a number of horizontal trays of parallel laths, the direction of each layer of laths being at right angles to the trays above and below it. The effect in plan view is of a grid composed of 2 in. square network, and the water upon being discharged through the trough walls flows down the grid packing in an even film, changing direction through 90° in every 2 in. down the whole depth of the stack.

This method of distribution ensures that the entire surface of the packing is evenly wetted, providing a very high heat exchange coefficient, which, together with the fact that the cooling air has a relatively unimpeded flow throughout, effects an economy in the cost of the power to drive the fans. Also, by completely avoiding the formation of water drops, there is a smaller loss of water by entrainment, and the use of baffle plates and drift eliminators is unnecessary.

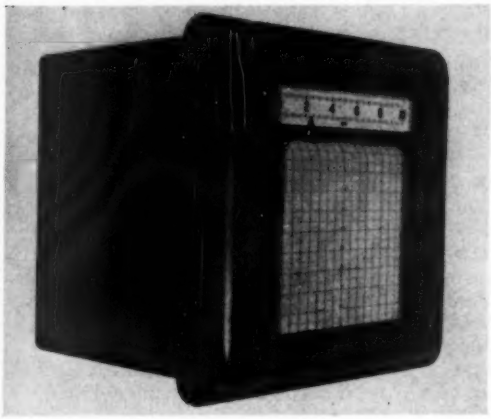
The salient feature of the film flow system, however, is the saving in space, as the packing depth can be reduced in some cases by as much as 50% of the space required by the normal drip bar packing system. This is reflected in both lower capital costs and in considerable saving of the power required to obtain the pumping head.

Film Cooling Towers (1925) *Ltd., Kew Bridge, Brentford, Middlesex.*

Electronic Strip-Chart Recorder

GEORGE KENT, LTD., announce the addition of the Mark 3 Multelec high-speed electronic strip-chart indicator-recorder (hitherto confined to nuclear-energy and other special applications) to their general industrial range of instrumentation and control. The Mark 3 is at present available for the precision measurement of millivoltage, and also temperature, in association with thermocouple, resistance thermometer or radiation pyrometer.

There are many features worthy of note, among them being an operating speed—with no pointer "overshoot"—of two seconds only for full-scale travel; all-mains operation with continuous standardization; re-designed chart-drive unit, permitting variation of chart speeds from 1 in. per hour to 4 in. per minute; 10 in. chart



width and pen travel; extremely sensitive, high-gain amplifier, covering a wide range of A.C. or D.C. input conditions; sealed-unit maintenance-free servo-motor with built-in tachogenerator; and a synchronous converter claimed to be capable of detecting smaller signals than any other available. The last three components, developed as a result of extensive research, are available for other applications as separate units.

The Mark 3 Multelec is available in single- or multi-point form, with point-cycle times of 5, 10 or 20 seconds, depending on application, enabling up to sixteen variables consecutively to be measured and recorded with laboratory accuracy. The Kent policy of rationalized manufacturing design offers valuable user-benefits, such as interchangeable plug-in-unit construction coupled with maximum accessibility, minimum maintenance, and a reduction in the number of spare-parts it is necessary to carry.

George Kent, Ltd., Luton, Beds.

Document-Copying Machine

A NEW, low-cost document-copying machine, the Azoflex Combine 105, which is capable of turning out copies from any translucent original at the rate of two-a-minute, has recently been introduced by Ilford, Ltd. The size and weight of the machine are roughly those of a typewriter, and the following advantages are claimed: (*a*) it requires no darkroom, running water, or other photographic procedure; (*b*) it can be switched on and used immediately without stopping for the light source to warm up; and (*c*) it can be operated by anyone without previous experience. Opaque documents can be copied by the use of a reflex foil, and half-tone illustrations can also be duplicated.

Its speed is due, in part, to a new ultra-fast sensitised paper, Azoflex FB, which Ilford have produced especially for this machine. The new paper is said to be at least 33⅓% faster, with the same degree of contrast, than existing papers. Prints are made by placing the document in contact with the sensitised paper and inserting them both in turn into the exposing and developing sections of the machine. The developer is an alkaline solution which is completely harmless. At the end of the day, the entire developing mechanism is lifted out in one simple operation for emptying and rinsing. No other daily cleaning is necessary.

Ilford, Ltd., Ilford, Essex.

CURRENT LITERATURE

Book Notices

EFFECT OF A SURFACE-ACTIVE MEDIUM ON THE DEFORMATION OF METALS

By V. I. Likhtman, P. A. Rebinder and G. V. Karpenks. Translation from the Russian, 188 pp.; numerous illustrations, graphs and sketches; 101 references. London, 1958, H. M. Stationery Office. 15s. net.

THIS monograph reports the very extensive work by Russian scientists on the effects of environment, in particular liquid surface-active media, on the mechanical properties of metals. Most of the work described was carried out during the past twenty years at the Department of Disperse Systems in the U.S.S.R. Academy of Sciences Institute of Physical Chemistry, but some of it was undertaken by Karpenks under the auspices of the Ukranian S.S.R. Academy of Sciences.

The programme of work undertaken led to the discovery of a number of new effects resulting from the interaction—chiefly by adsorption—between a deformed metal and the surrounding medium containing a surface active agent. They include a lowering of the yield point of metal single crystals, peculiar modifications in the surface structure of metals, an increase in creep rate, a reduction in fatigue strength, and a deformation-assisting electro-capillary effect.

On the interpretation of the increase in creep rate due to absorption, the Russian workers consider that the principal effects are attributable to the interaction between the metal and its surrounding medium through absorption. This is in line with the conclusions of the German metal physicist Masing and his co-workers, and opposed to the view of Andrade's group at Cambridge, who interpreted the phenomenon in terms of disruption of the oxide layer normally present on a metal surface by the surface-active agent.

This new field of research, which borders on solid state physics, metallurgy and the physical chemistry of solid state phenomena, is of considerable interest, as it points to new methods of controlling the microstructure and fundamental properties of metals and alloys. Such phenomena are, naturally, of practical importance during metal-working operations and in actual service conditions.

INTRODUCTION TO THE THEORETICAL AND EXPERIMENTAL ANALYSIS OF STRESS AND STRAIN

By A. J. Durelli, E. A. Phillips and C. H. Tsao. 498 pp., including index. 1958, New York, Toronto and London, Mr. McGraw Hill Publishing Co., Ltd. 97s.

THIS book bridges the gap between the conventional publications on strength of materials and the practical instructions on how to use experimental methods of stress analysis. The authors have set out to probe into the basic theories of stress, strain and elasticity in order to develop the student's critical appreciation of these subjects. This they achieve very well so long as the student bears in mind all the time as the authors warn him to do, the practical significance of what he is doing.

The book is divided into two sections. The first deals with the theories of stress, strain and elasticity, and demonstrates the analytical methods of determining the stress distribution in some two- and three-dimensional systems of loading on a body. It deals exhaustively with the problem of the stress distribution round a hole in a loaded plate. The second half deals with a number of methods of determining stress distribution experimenallyt These include the measurement of the deformation of grids on deformable models, brittle lacquer coatings, and mechanical strain gauges. The theory of the first part of the book is applied to the interpretation of results using the different experimental methods, and again the problem of the hole in a plate under load is dealt with very thoroughly by each method. The authors promise a further book in which more methods of experimental stress analysis will be described. A chapter on statistical methods applied to stress analysis forms a useful introduction to the subject, and serves to remind the experimental worker that precise stress measurement and calculation may be subject to variations which require careful interpretation.

This is not a book for ready reference, but is recommended as a course of study for graduate standard technicians who wish to make themselves thoroughly familiar with experimental methods of stress analysis.

R.G.H.

Trade Publications

THE abstracts contained in the January issue of *The Nickel Bulletin* form an apt illustration of the immense importance of nickel in every branch of industry. In the general field of nickel plating, reference is made to electrodeposition of black nickel, tin-nickel and hard carbide/nickel coatings. The section dealing with non-ferrous alloys includes abstracts of papers on physical and magnetic properties and the influence of the nickel content of copper alloys on susceptibility to intergranular cavitation. Attention is directed to several papers on high-strength steels, while abstracts typical of those falling under the generic head of heat- and corrosion-resisting materials relate, *inter alia*, to literature on structure and properties of nickel-containing high-temperature alloys and steels, erosion- and corrosion-resistance of materials to steam generated by nuclear power plants, and prevention of stress corrosion. The issue also contains the first of the quarterly reviews of recent patent literature.

Cyanamid International is offering a technical publication entitled "Chemistry of Cyanidation," which deals with the chemistry of complex gold and precious metal ores. The publication provides an analysis of the problems inherent in cyanidation of ores containing copper, zinc, nickel, arsenic and antimony, carbonaceous materials, sulphide minerals and reagents used for the flotation process. A copy may be obtained on request to the General Chemicals Division, Cyanamid of Great Britain, Ltd., Bush House, Aldwych, London, W.C.2.

A LEAFLET received from Ascog, Ltd., shows at a glance the principal types of Lechler spray nozzles for atomising liquids. They are made in a variety of materials and in a number of special purpose constructions to meet the widest possible range of requirements. Among the

descaling and the cooling of rolls and rolled products, and in coke oven plants for gas cooling and purification, coke quenching, and dust laying.

THE theme of a recent High Duty Alloys leaflet—"Pressure Die Casting in Hiduminium"—is the saving which can be effected in subsequent machining and assembly by the use of die castings. Details are given of the physical and mechanical properties of Hiduminium 00 and Hiduminium 10, corresponding to B.S. 1490 LM2 and LM6, respectively, and a comparison is made from the production angle between a component produced by blanking, forming and assembling parts from sheet, and the same component redesigned as a pressure die casting.

Kaye Alloy Castings, Ltd., have marked their Silver Jubilee by issuing a glossy colour brochure illustrating some of the stages through which their whole range of die castings must pass before leaving the firms' three foundries. After pointing out that it is not always possible to reproduce internal forms by means of metal coring, the brochure refers to the development of a technique using shell-blown destructible cores which permit the achievement of a high degree of consistency and fine finish.

THE eighth issue of *Inco-Mond Magazine*, which is now available, includes an article on the preparation of Ribena, the blackcurrant concentrate claimed to be the richest source of Vitamin C. Other articles deal with the origin and development of the Yale lock; the formal testing of coins at the Royal Mint; the new London planetarium; and the work carried out at the world's largest corrosion testing station on the coast of North Carolina. Two new films produced by the Mond Nickel Company film unit are described. *Inco-Mond Magazine* is obtainable free on request from the Mond Nickel Co., Ltd.

BONDERIZING covers a range of processes for the treatment of iron, steel, aluminium, zinc and cadmium surfaces. The treatment is normally carried out in a hot Bonderizing solution, and the result is the conversion of the surface of the metal into a non-metallic phosphate coating which, when painted, lacquered or enamelled, provides an effective corrosion inhibitor, prevents spread of corrosion beneath the paint, and provides a key for all types of organic finishes. An illustrated booklet recently issued by the Metal Finishing Division of The Pyrene Co., Ltd., describes the various techniques for carrying out the process.

"OUR ROLLING PIONEERS"—an article appearing in a recent issue of *The Forge*, the house journal of the Brockhouse Organisation—tells the story of a company whose products form an integral part of every industry where sheet metal is used. Reference is made to the part played by the firm, Warwick Rim and Sectioning Co., Ltd., in the battle against corrosion, in the development of nuclear energy, and in industries such as mining, agriculture, railways, aviation, motor transport and accoustics. Other features in this issue deal with the cleansing of runways at London Airport and the marketing of Indian motor cycles in the U.S.A.

THE January issue of *I.M.P.* (*In the Melting Pot*) is devoted to the results of the "Miss Suprex" competition, organised by The Morgan Crucible Co., Ltd., to establish the longevity of Suprex crucibles. The winner in the section for copper base alloys was The Argus Foundry Co., Ltd., of Glasgow, with 226 heats in a T.P.C. 400 crucible which was still serviceable. In the light alloy section, Sturla's Bronze Foundry Co., Ltd., obtained 322 heats from a CC150 crucible, and again it was still fit for further use.

THE advent of direct-reading instruments has greatly widened the scope of spectrographic analysis and the speed with which it is possible to determine the amounts of a relatively large number of elements in a metal or alloy has been particularly appreciated in controlling melting and refining processes. A new Hilger & Watts booklet describes the direct-reading spectrographs made by the company. These include the 3 metre grating polychromator; medium direct readers; the fluorite polychromator; and the metal ratio analyser. Another recent Hilger & Watts catalogue features digitizers and other equipment for data processing.

TRI-MOR DENSE GUNCRETE is the subject of the latest leaflet of Morgan Refractories, Ltd. This is a refractory material developed for application by means of a cement gun. It will withstand temperatures up to 1,300° C., and is quite plastic when mixed with water; it has a very low rebound loss when "gunned." In service its behaviour is very similar to that of a normal refractory concrete. The advantage of refractories which can be gunned lies in the fact that large constructions can be quickly fabricated using a very small labour force and without expensive shuttering. Tri-Mor Dense Guncrete can be used in conjunction with metal or ceramic anchors, and, because of its highly plastic nature it can be used for patching spalled and eroded brickwork.

Books Received

"The Physical Chemistry of Steelmaking." By J. Elliott. Proceedings of the Conference on "The Physical Chemistry of Iron and Steelmaking" at Endicott House, Dedham, Massachusetts, from May 28th to June 3rd, 1956. Sponsored by Department of Metallurgy, Massachusetts Institute of Technology. 257 pp. inc. index. Published jointly by The Technology Press of The Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York. London, 1958. Chapman and Hall, Ltd. 120s. net.

"Kempe's Engineers' Year-Book, 1959," Vols. I and II, with index. London, 1959. Morgan Brothers (Publishers), Ltd. Price (two volumes in case) 82s. 6d. Postage extra.

"Lindsay's International Register of Wire Rod and Strip—1957–1958," Wolverhampton, 1958. Lindsay's Wire Publications. 25s.

"Conduction of Heat in Solids." By H. S. Carslaw and J. C. Jaeger. Second Edition. 510 pp. inc. author and subject indexes. Clarendon Press: Oxford University Press, 1959. 84s. net.

"Vacuum Metallurgy." Edited by R. F. Bunshah. Lectures presented during the course on Vacuum Metallurgy sponsored by the Department of Metallurgical Engineering in co-operation with the Office of Special Service to Business and Industry, New York University, June 10th–14th, 1957. 472 pp. inc. subject and author indexes. New York and London, 1958. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 100s. net.

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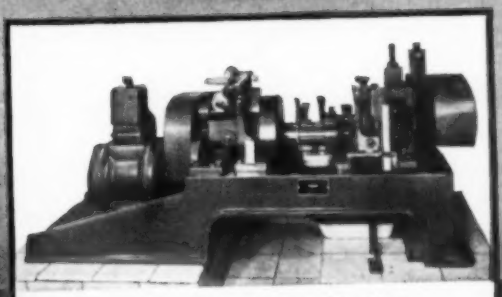

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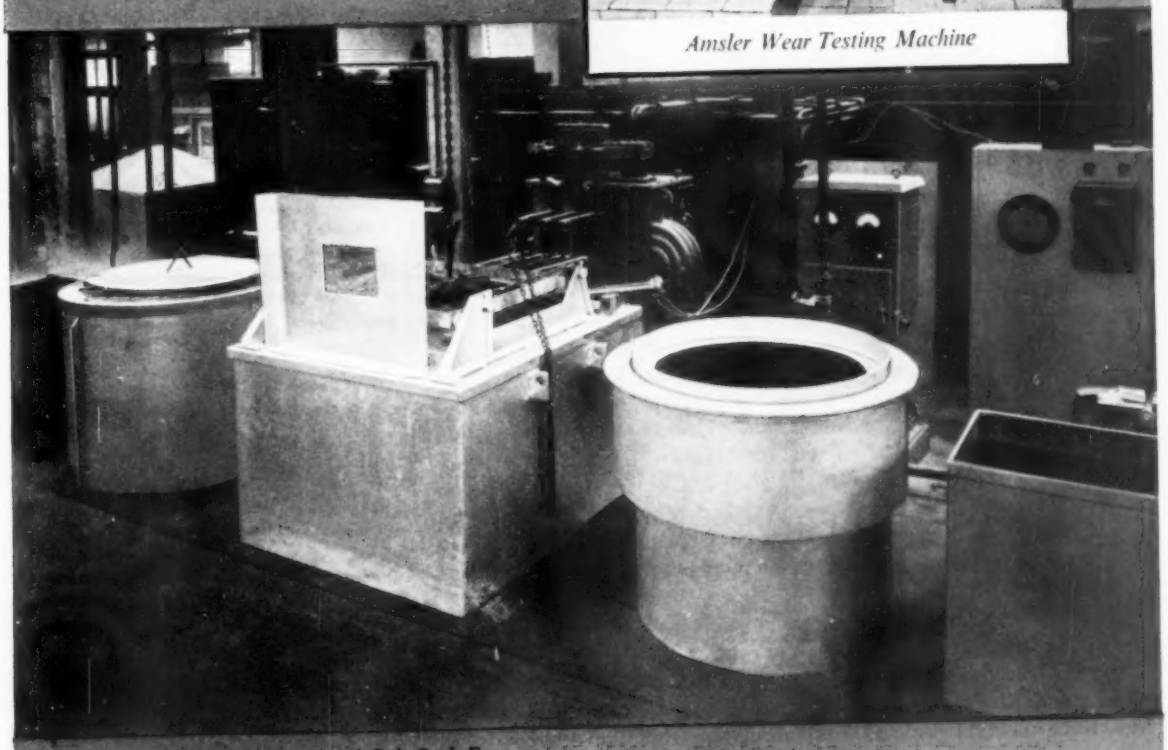

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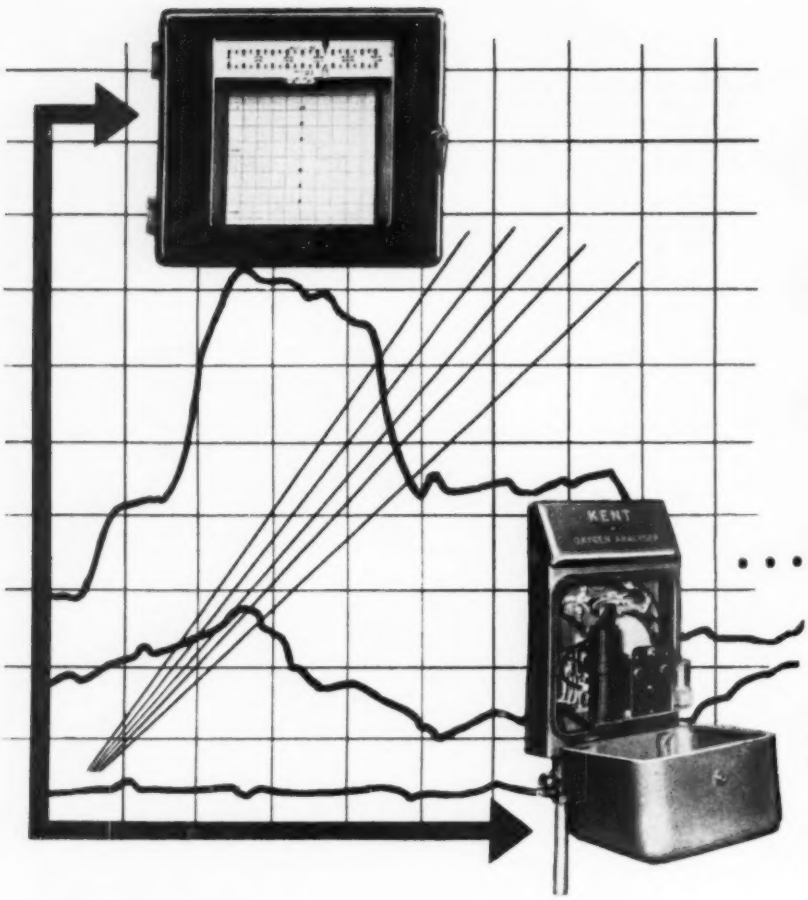

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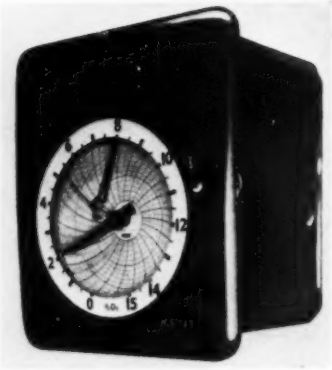

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LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
MARCH, 1959 Vol. LIX, No. 353

A Composite Procedure for the Colorimetric Determination of Eleven Elements in Aluminium

By M. C. Steele, M.Sc., A.S.T.C., F.R.A.C.I., and L. J. England, A.S.T.C.

Metal Manufacturers Ltd., Port Kem'la, N.S.W., Australia.

A composite procedure is described, based on a 1 g. sample, for the colorimetric determination of small quantities of elements which might be found in aluminium. The eleven elements concerned are iron, copper, silicon, chromium, nickel, zinc, manganese, titanium, vanadium, magnesium and lead.

A PROCEDURE has been developed for the colorimetric determination of eleven elements in aluminium based on a 1g. sample. Iron is determined by the thiocyanate method, copper using diethyldithiocarbamate, silicon as silicomolybdate, chromium by the diphenylcarbazide method, nickel using dimethylglyoxime, zinc using dithizone, manganese by converting to permanganate with periodate, titanium and vanadium as pertitanic and pervanadic acids, magnesium as a lake with Titan Yellow, and lead as the dithizone complex.

General Considerations

This proposed procedure was designed to cover the small quantities of elements which might be found in aluminium. In some cases, however, such as manganese, chromium and titanium, when these elements are additives, the procedure of colorimetric comparison against a reagent blank is adequate, in others it would be advantageous to adopt precision photometric techniques. However, when the magnesium content is 2% or greater, the titration with E.D.T.A. method is recommended, and for high zinc, lead and nickel, polarographic methods are preferable.

The Sample Solution

The acid mixture—sulphuric and nitric—does not interfere with the reagents used in the various methods making up the composite procedure described.

Iron

The thiocyanate method has been chosen instead of the phenanthroline method, because the acid mixture used in the sample solution can be used for all the determinations without interference. The only element which will interfere with the thiocyanate method is chromium VI. It was found experimentally that 1% chromium raises the true iron content by about 3% of the amount present. As the chromium is not likely to be above 0·35%, a maximum error of 1% of the iron content can be expected. The iron thiocyanate, $[Fe(CNS)_6]^{-3}$, is temperature dependent, and a 1% decrease in extinction occurs for each °C. rise in temperature[1,2]. This has been confirmed; calibration and measurement temperatures are, therefore, important. Titanium does not interfere and the effect of any red $[V(CNS)_6]^{-3}$ present is negligible. The first indication of possible interference due to aluminium was observed when plotting absorption graphs of the $[Fe(CNS)_6]^{-3}$ ions against reagent blanks with and without aluminium. The former gave maximum absorbence at 4,400–4,500Å and the latter at 4,550–4,600Å. Compensation for this shift in transmission is made by calibrating in the presence of aluminium.

Copper

Sodium diethyldithiocarbamate gives a strongly coloured golden-brown turbidity with small amounts of copper ions. In the presence of a colloid such as gum acacia, an apparently clear yellow solution is obtained. The complex is extractable in various organic solvents.

Iron, as ferric citrate, interferes to the extent that 1% iron is equivalent to 0·001% copper at 440mμ. Silicon up to 3% gave negligible interference, which is not significant with low iron content. Zinc, nickel and lead form uncoloured complexes with diethyldithiocarbamate, which, when present, can be removed by increasing the addition of ammonium hydroxide. Manganese, magnesium, and chromium do not interfere. Bismuth, however, forms a yellow-green compound which is insoluble in ammoniacal solution. This may be filtered, or another aliquot can be taken, the copper complexed with cyanide, the colour due to bismuth determined and the copper obtained by difference.

From transmission curves maximum absorbence occurs at 4,400Å and readings are made at this wavelength.

Silicon

Whilst it is preferable to use platinum ware when digesting the aluminium sample with sodium hydroxide solution, satisfactory results are obtained using unetched Pyrex glass. The magnitude of the aliquot taken may depend on the amount of silicon present; for low silicon, a 10 ml. aliquot is sufficient, especially if a photomultiplier is used with the Beckman Spectrophotometer.

The silico-molybdate method has no interference from the elements expected in aluminium.

Chromium

In the chromium-diphenylcarbazide system, 3 moles of diphenylcarbazide will react with 2 moles of chromium VI to form a chromium III-diphenylcarbazide complex. The chromium III has been shown to exist by magnetic susceptibility measurements[6]. It is, however, necessary to have the chromium in the hexavalent state before complexing for colorimetric work.

Various oxidants have been tried—ammonium persulphate[3], perchloric acid[4], permanganate[5], and others. Of these, permanganate gave the quickest results commensurate with accuracy.

Elements usually found in aluminium do not markedly affect the determination[4]. Iron, as ferrous iron, interferes, but as this is oxidised to the ferric state its effect is eradicated.

Chromium as low as 0·0005% can be determined by the method described.

Nickel

The colorimetric determination of nickel using dimethylglyoxime depends on the formation of the nickel IV-dimethylglyoxime complex, the maximum absorbence of which occurs at 4,300Å.

A transmittance curve using copper and no nickel showed no indication of the formation of any soluble copper dimethylglyoxime complex, and no precipitate formed with sufficient ammonium citrate. Using the described procedure, copper showed little effect on the readings for nickel between 30 minutes and at least 16 hours (Table I); the interference being the same at 430 mμ and 530 mμ.

TABLE I—EFFECT OF COPPER ON READINGS FOR NICKEL at 530 mμ

Nickel Present (%)							
0·3	Copper Present (%)	0·00	0·20	0·60	1·00	2·00	5·00
	Transmittance (%)	70	70	70	69½	69½	69
0·6	Copper Present (%)	0·00	0·20	0·60	1·00	2·00	5·00
	Transmittance (%)	53	53	53	52½	52½	52
0·0	Copper Present (%)	0·00	0·20	0·60	1·00	2·00	5·00
	Transmittance (%)	100	100	100	99½	99½	99

If the solution is not allowed to stand after the addition of iodine and before the addition of dimethylglyoxime, the effect of copper is more marked and fading of colour occurs which is accelerated with increasing copper content. Also the colour is stable from 5 to 10 minutes only. When the solution is allowed to stand after the addition of iodine and before the addition of dimethylglyoxime, stability of colour takes a longer time (30 minutes), but a stable equilibrium then exists. It is uncertain whether this standing time allows the nickel to be more completely in the quadrivalent state or whether some other equilibrium condition is involved. Magnetic susceptibility studies would no doubt establish the question of the nickel IV state.

Iron, probably as ferric citrate, interferes, but this interference is insignificant below 0·6% iron. The effect of iron, using the described procedure, on transmittance readings is shown in Table II for 0·00% nickel, 0·30% nickel and 0·60% nickel. The colour was stable after 30 minutes and for at least 16 hours.

Table II shows the probable reason for most workers using a 530 mμ wavelength, as the effect of the yellow ferric citrate is avoided at 0·4% iron. This, of course, is at the expense of greater sensitivity at 430 mμ. The

TABLE II—EFFECT OF IRON ON READINGS FOR NICKEL

Nickel (%)	Iron (%)	Transmittance (%)	
		at 430 mμ	at 530 mμ
0·00	0·00	100	100
	0·20	99½	100
	0·40	99½	100
	0·60	98	99¼
	1·00	96½	98½
	2·00	93	97
	4·00	85	94
0·30	0·00	65	70
	0·20	64½	70
	0·40	64½	70
	0·60	63½	69¼
	1·00	62½	69
	2·00	60	68
	4·00	55	66
0·60	0·00	49	53
	0·20	48½	53
	0·40	48½	53½
	0·60	48	52½
	1·00	47	52½
	2·00	45	51½
	4·00	42½	50

effects of other elements which might be expected in aluminium are negligible.

Zinc

The method for zinc uses the prepared solution for copper as diethyldithiocarbamate does not interfere with dithizone. As this solution is ammoniacal and contains no cyanide, the red zinc-dithizone complex is developed and subsequently extracted with an organic solvent (CCl_4).

Titanium and Vanadium

As the peaks in the transmittance curves of pertitanic acid and pervanadic acids are sharp at optimums of 4,100 and 4,000Å, respectively, care must be taken to isolate these wavelengths in the determinations. Negligible interference from other elements occurs at these wavelengths.

Magnesium

Of various amines tried for masking aluminium, triethanolamine[8] was the most satisfactory. Although an order of additions is given in the method, once the triethanolamine has been added, the other reagents may be added together without any noticeable effect on the lake formation.

Iron, silicon, nickel, titanium, vanadium, and zinc in amounts up to 5% do not interfere. Copper up to 1% does not interfere, but there is a small effect when present in the range 2–5%. Chromium does not interfere up to 0·5%, and this covers the expected chromium additions to aluminium in alloys. However, at 2–5% chromium some inhibition of colour formation occurs, giving a slightly low result. Lead also gives low results when present above 0·5%. Manganese gives results 0·03–0·18% too high, and from the figures quoted in Table III an error of 3% of the magnesium content can be expected for each 1% of manganese present. Transmission studies show that the manganese is present as manganese citrate. The effect of interferences of copper, chromium, manganese and lead with the method are shown in Table III. Iron, silicon, nickel, titanium, vanadium, and zinc in amounts up to 5% of each do not interfere.

Tartaric, citric, boric and oxalic acids have been used in the formation of buffers. Full colour development with tartaric acid took 16 hours, and with boric acid

TABLE III—MAGNESIUM RESULTS IN THE PRESENCE OF POSSIBLE INTERFERENCE

Element	Amount Present (%)	Magnesium Present (%)	Magnesium Found (%)	
			Uncorrected	Corrected
Copper	0·5	1·10	1·10	1·10
	2·0		1·11	1·10
	5·0		1·12	1·09
Chromium	0·5	1·10	1·10	1·10
	2·0		1·09	1·10
	5·0		1·08	1·11
Manganese	0·5	1·10	1·15	1·10
	2·0		1·17	1·10
	5·0		1·28	1·11
Lead	0·5	1·10	1·10	1·10
	2·0		1·08	1·09
	5·0		1·04	1·09

½ hour; in the presence of oxalic acid a precipitate was formed, whilst with citric acid colour formation was instantaneous. Ammonium ions must not be present as these inhibit[9] any colour development. The Titan Yellow-magnesium system does not obey Beer's Law, but adequate calibration curves can be drawn. Maximum absorbence is at 5,000Å.

Lead

By using a wavelength of 5,200Å, absorption due to dithizone only is avoided. Zinc may interfere in high percentages[7], but no interference was observed with zinc up to 2%, using cyanide for complexing.

Apparatus

A Beckman Spectrophotometer Model B or an Evelyn Colorimeter.

Detailed Procedure

Sample Solution Preparation

Reagents

Sodium Hydroxide Solution (20%)
Mixed Acid Solution—5 parts sulphuric acid (s.g. 1·84), 1 part nitric acid (s.g. 1·42) and 5 parts distilled water.

Procedure

Digest 1·000 g. sample with sodium hydroxide solution (20 ml.) in a 250 ml. beaker. Add 20 ml. mixed acid. Boil to a clear solution and dilute to approximately 50 ml. Cool and dilute to 100 ml. in a volumetric flask.

Iron

Reagents

Ammonium Thiocyanate Solution (10%)

Procedure

Transfer a 10 ml. aliquot to a 250 ml. beaker. Add 10 ml. thiocyanate solution, with stirring during the addition. Dilute to 100 ml. in volumetric flask. Compare colorimetrically with the reagent blank at 470 mμ. The temperature of the solution must be the same as the calibration solutions. Transmittance readings are read against calibration curves which are made with aluminium present.

Copper

Reagents

Ammonium Citrate Solution—500 g. citric acid and 500 ml. ammonia (s.g. 0·88), make up to 1 litre.
Ammonium Hydroxide Solution (1 : 3).
Gum Acacia Solution (0·5%).
Sodium Diethyldithiocarbamate Solution (0·2%).

Procedure

Transfer a 10 ml. aliquot to a 250 ml. beaker. Add in the following order ammonium citrate solution (2 ml.), ammonium hydroxide (20 ml.), gum acacia solution (10 ml.) and dithiocarbamate solution (10 ml.). Dilute to 100 ml. in a volumetric flask. Compare colorimetrically with the reagent blank at 440 mμ. Keep all of the solution in case a zinc determination is required. Zinc does not interfere up to 0·1%. If a zinc diethyl dithiocarbamate forms it can be dissolved by increasing the ammonium hydroxide concentration.

Silicon

Reagent

Ammonium Molybdate Solution (10%).

Procedure

Transfer a 10 ml. aliquot, or another appropriate aliquot, to a 250 ml. beaker. Add 5 ml. ammonium molybdate solution and boil for about one minute. Cool and dilute to 100 ml. in a volumetric flask. Compare colorimetrically against a reagent blank at 340 mμ.

Chromium

Reagents

Potassium Permanganate Solution (saturated).
Hydrochloric Acid (concentrated).
Diphenyl Carbazide Solution (0·1%).

Procedure

Transfer a 5 ml. aliquot to a 250 ml. beaker. Add approximately 10 ml. distilled water and 5 drops of permanganate solution. Boil 2–3 minutes and slowly add hydrochloric acid drop by drop to destroy the excess permanganate (the solution then being clear). Cool and dilute to approximately 60 ml. Add 5 ml. fresh diphenyl carbazide reagent. Dilute to 100 ml. in a volumetric flask and compare with a reagent blank at 540 mμ within 15 minutes.

Nickel

Reagents

Iodine Solution—Saturated in a 100 g./l. potassium iodide solution.
Dimethylglyoxime—1% solution in concentrated ammonium hydroxide.
Ammonium Citrate Solution—500 g. citric acid and 500 ml. ammonia (s.g. 0·88), diluted to 1 litre.

Procedure

Transfer a 5 ml. aliquot to a 250 ml. beaker. Add 2 ml. ammonium citrate solution, 75 ml. water and 2 ml. of iodine solution. Stand for 15 minutes, then add 15 ml. dimethylglyoxime solution. Dilute to 250 ml. in a volumetric flask, and compare with a reagent blank at 430 mμ or 530 mμ after 30 minutes.

Zinc

Reagent

Dithizone Solution—1·0 g. dissolved in 1 litre of carbon tetrachloride and filtered. The solution is stable for two weeks and must be kept in a dark bottle.

Procedure

Transfer a 50 ml. aliquot from the prepared solution for the copper determination to a 250 ml. beaker. Add 20 ml. dithizone solution. Separate the lower layer and dilute to 100 ml. with carbon tetrachloride. Compare colorimetrically against a reagent blank at 530 mμ.

Manganese

Reagents

Nitro-Sulphuric-Phosphoric Acid Solution—3 parts water, 1 part nitric acid, 1 part sulphuric acid and 1 part phosphoric acid.

Potassium Periodate

Procedure

Transfer a 10 ml. aliquot to a 250 ml. beaker. Add 5 ml. of nitro-sulphuric-phosphoric acid solution and boil. Then add approximately 0·2 g. solid potassium periodate. Boil for about 2 minutes, cool and dilute to 200 ml. in a volumetric flask and compare with a reagent blank at 520 mμ.

Titanium and Vanadium

Reagent

Hydrogen Peroxide (30%).

Procedure

Transfer a 10 ml. aliquot to a 25 ml. volumetric flask. Add 2 ml. of hydrogen peroxide and dilute to mark on flask. Colorimetric measurements are made at 410 mμ for titanium and at 400 mμ for vanadium. These are compared against another aliquot containing no peroxide addition.

Magnesium

Reagents

Titan Yellow Solution (0·02%).
Sodium Hydroxide Solution (20%).
Triethanolamine (20%).
Gum Acacia Solution (0·5%)
Citric Acid Solution (20%).

Procedure

Transfer a 10 ml. aliquot to a 250 ml. beaker. Firstly add 25 ml. of triethanolamine. Then add approximately 5 ml. citric acid. Add 15 ml. of Titan Yellow solution, then 20 ml. of gum acacia solution followed by 15 ml. of sodium hydroxide solution. Dilute to 100 ml. in volumetric flask and compare against a reagent blank at 500 mμ, after 5 minutes.

Lead

Reagents

Potassium Cyanide Solution (10%).
Dithizone (as used for zinc determination).
Ammonium Citrate Solution (as used for copper determination).
Ammonium Hydroxide (s.g. 0·88).

Procedure

Transfer 10 ml. aliquot to a 250 ml. beaker. Add 10 ml. citrate solution, 10 ml. ammonium hydroxide and 2 ml. potassium cyanide solution. Add 20 ml. dithizone solution and extract the complex with (two extractions of 10 ml.) carbon tetrachloride. Compare with reagent blank at 520 mμ.

Calibration curves or tables are made in all cases and the usual procedures for their construction are used.

REFERENCES

1 Rogina, B. and Dubravcic, M., *Analyst*, 78, 594, (1953).
2 Quenston, T. C. J. and Parker, C. A., *Anal. Chim. Acta.*, **3**, 277, (1949).
3 Charlot, G. and Gauguin, R., "Dosages Colorimétriques, Principes et Méthodes." Libraires de L'Académie de Medecine, Paris, 1952.
4 "A.S.T.M. Methods of Analysis of Metals" E34–56, 1956, p.398.
5 "Analysis of Aluminium and its Alloys," The British Aluminium Co. Ltd., England, 1941, p.45.
6 Das Sarma, B. and Ray, J. N., *Sci. and Culture* (India), **21**, 477, (1956).
7 Snell, F. D. and Snell, C. T., "Colorimetric Methods of Analysis" Vol. II, Van Nostrand & Co., Inc., New York, 1949, p.36.
8 Pribil, R., *Chem. listy*, **48**, 382, (1954).
9 Young, A., Sweet, T. R. and Baker, B. B., *Anal. Chem.*, **27**, 356, (1955).

Iron and Steel Translation Service

A translation of any article on iron and steel manufacture in the foreign technical press can now be provided at a fraction of the translating cost, provided that three requests for it are received by the British Iron and Steel Industry Translation Service. This Service is run by The Iron and Steel Institute with the collaboration of several large companies and of the British Iron and Steel Research Association. Some 530 translations are already available—a large proportion of them from German or Russian.

Requests for new translations are invited from all, members and non-members alike, in Great Britain and abroad. Anyone requiring a translation of an article on iron and steel manufacture should send a request to B.I.S.I.T.S., who will check that no translation already exists, and then circulate particulars to members (and some others). Then, if further requests are received, B.I.S.I.T.S. will commission a translation; if only one other company is interested, it and the original enquirer are invited to share the cost of translation. When no other request is received, B.I.S.I.T.S. can arrange a translation privately; if it is needed urgently it is made at once, without waiting for the above procedure.

A complete list of the first year's translations, classified by subject, is now available; it is kept up-to-date by fortnightly lists (with classified cumulations every six weeks). All translations are also listed in the *Journal of the Iron and Steel Institute*, and in the B.I.S.R.A. Report List. In addition, lists of translation in preparation are issued, to notify in advance those who themselves make translations. Several technical journals list translations of particular interest to their readers. It is, however, not advisable to rely on these lists as a complete guide to the foreign literature; the abstracts and indexes in the *Journal of the Iron and Steel Institute* provide a comprehensive survey, on the basis of which enquiries for translations may be made. B.I.S.I.T.S. maintains a card index of translations made by several other organisations in Great Britain, the U.S.A., and (in the case of translations from Eastern languages) Germany and France.

Enquiries are welcomed and should be addressed to the British Iron and Steel Industry Translation Service, The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1.

New Instrument Laboratory

Construction has commenced of the new Research Laboratory for the Cambridge Instrument Company. Overlooking the River Cam and Jesus Green, and within ten minutes walk of the centre of Cambridge, the 20,000 sq. ft. building will provide an imposing frontage for the Cambridge factory. The top floor, with generous roof lighting, will form an ideal design and drawing office, and the three floors below are being fitted with the latest equipment for instrument work involving physics, chemistry, electronics and precision engineering.

Exhibits of Metallurgical Interest at the Physical Society's Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception, and in this issue we continue a short series of reviews in which such items will be described.

X-Ray Fluorescence Spectrometer

THE Raymax 60 X-ray generator, with a constant potential high voltage generator, spectrometer and counting gear was shown by Metropolitan-Vickers Electrical Co., Ltd. The demountable X-ray tube energised with a D.C. supply may be operated at 60 kV. and 25mA. with a focus of 1 mm., while the independent negative voltage applied to the cathode shield may be used to reduce the focus to 100 microns. The high voltage applied to the X-ray tube is maintained constant by a stabilizer in the control, and the tube current is likewise maintained within $\pm 0{\cdot}1\%$ by an emission stabilizer.

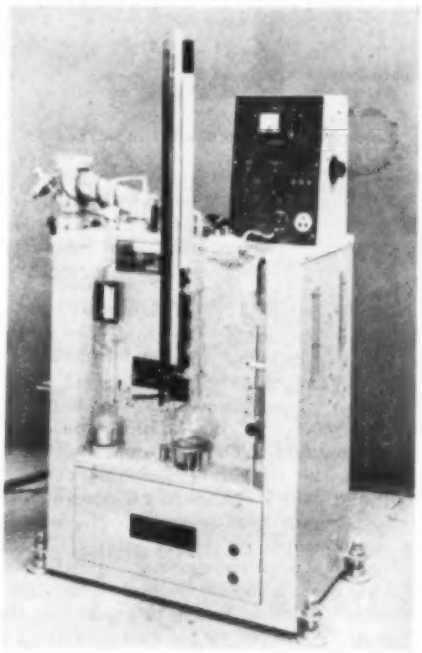
The spectrometer includes a base assembly housing the motor and gears driving two independent coaxial worm wheels, sample holder beam slits, Soller slit, crystal holder and X-ray detector support. The motor drive and gears provide speeds of $\frac{1}{4}$, $\frac{1}{2}$, 1, 2 and 4 degrees per min. Micrometer dials mounted on each worm shaft read 1° per turn in intervals of 0·01°. In addition to the X-ray detector, with its ratemeter and scaling unit, a monitor counter is provided with its own ratemeter and scaling unit for the utmost accuracy in fluorescence analysis. The diffracted beam may be measured, with the number of counts determined by the chosen number reaching the monitor detector. The two ratemeters may be similarly interconnected and the result shown on a ratio recorder.

Analyses of specimens can thus be made quickly and accurately for one or more elements and the results presented either as a graphical record or a tabulation, without damage to the specimen. Accessories are also available for converting the spectrometer for the direct measurement of diffracted intensities with the option of the monitor if it is required.

Vacuum Fusion Gas Analysis

Metal construction is used wherever possible in the vacuum fusion gas analysis apparatus shown by Edwards High Vacuum, Ltd. It is a compact self-contained unit for the determination of oxygen, nitrogen and hydrogen in metal samples, and the aim in design has been to overcome the difficulties experienced with the all-glass equipment previously used.

The samples are melted in a vertical graphite crucible assembly contained in a water cooled silica furnace tube mounted in a stainless steel header, and can be introduced as required through a vacuum lock. The crucible is inductively heated to a maximum temperature of 2,400°C. by a 6 kW. high frequency generator. High speed evacuation of evolved gases is carried out by a Speedivac 2M4 mercury diffusion pump, which during primary evacuation, is backed by a secondary 1 in. diffusion pump and single stage rotary pump. The gas samples are extracted by the Speedivac type 2M4 diffusion pump and transferred to a Poepler pump, arranged to further compress them into a known volume from which they can either be circulated around an integral analysis system or taken away for separate treatment.

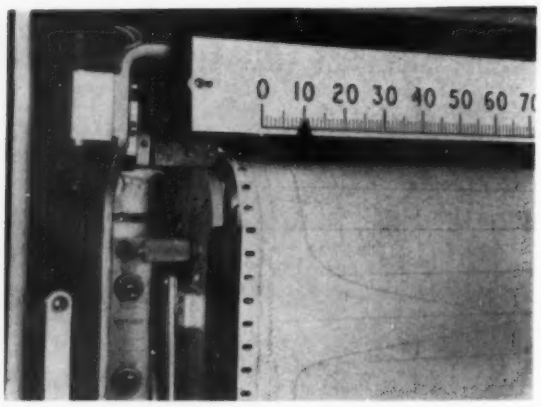


Courtesy of Edwards High Vacuum, Ltd.

Vacuum fusion gas analysis apparatus

Gas Chromatography Recorder

The Sunvic Controls exhibits included a potentiometric recorder, with an integration system suitable for use with gas chromatographs. The integrating system is fitted into a single trace recorder, potential from the retransmitting slidewire of which is fed to a low-inertia integrating motor. Shaft speed of this is directly proportional to the applied potential. Three sets of cam-operated contacts are included. A pair can be selected according to chart speed, and they make circuit at a frequency proportional to the deflection of the instrument. The contacts energise two solenoid-operated pens which record the time integral of each trace "peak" immediately beneath the peak. Amplitudes



Courtesy of Sunvic Controls, Ltd.

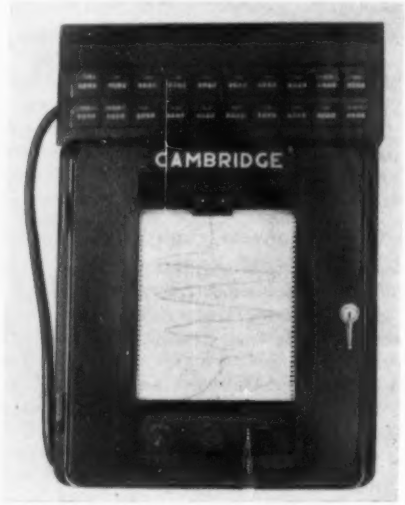
Single trace recorder fitted with integration system

between 10% and 100% f.s.d. can be integrated to better than 1%. Integration commences when the recorder input reaches 1% f.s.d. Output can also be fed to a mechanical counter either internal or external to the instrument.

Automatic Chart Analysis

Industrial quality control often makes it necessary to determine the percentage amount of material which falls within given tolerances. A typical case is the measurement of strip thickness, usually done manually by measuring a chart at about 1 in. intervals—a laborious and imprecise method. The instrument (patent applied for) shown on the Cambridge Instrument Company's stand, automatically "samples" a recorder chart at intervals of 1 mm. giving results of much greater statistical significance.

The output of a photo-electric "line detector" is amplified to feed a servo-motor. This causes the "line detector" itself to follow the record as the chart moves past it. The servo-motor also operates a series of limit switches, each feeding a counter. These correspond to the intervals between the given limits, and they are fed with pulses at a rate of one for each millimeter of chart drawn past. Each pulse will raise by one digit the counter in whose section the record trace falls at the time. The counter readings therefore show the distribution of the measured values between the given limits: percentages are derived arithmetically. The maximum chart speed (6 in./min.) is automatically decreased as necessary for the "line detector" to follow the steeper trace slopes.



Courtesy of The Cambridge Instrument Co., Ltd.

Automatic chart analyser

Autosonic Inspection Equipment for Czechoslovakia

A £10,000 ORDER for automatic ultrasonic inspection equipment has been placed with Kelvin Hughes (Industrial), Ltd., by KOVO the Czech. buying organisation, through EXICO of Sloane Street, S.W.1. The equipment will facilitate the rapid scanning of rolled mild steel bars for internal defects, and consists of a remote control console containing the c.r.t. presentation and recording equipment and the remote operating controls for a scanning unit situated above the main feed conveyor. Rolled mild steel bars of up to 7·9 in. (200 mm.) in diameter and moving at a speed of 98·5 ft./min. (30 m. min.) are scanned for internal defects, and are automatically marked and rejected if they contain defects in excess of a pre-determined degree.

New Oil Research Laboratories

IN the past ten years, the volume of research and development work in Wakefield-Dick's Laboratories at Hayes (Middlesex) has increased 300%. Now a large extension to the laboratories has been opened, which is completely equipped with the most modern apparatus used for research on lubricating oils and allied products.

In the new spectrographic laboratory, for instance, the equipment includes apparatus which analyses, spectrographically, the metallic constituents of an oil sample. In the radio-chemical laboratory, research is conducted with the aid of radioactive isotopes. Considerable attention has also been given to the provision of equipment and services for the more routine laboratory work. In the organic laboratory, each chemist is provided with separate compressed air, gas, vacuum and nitrogen supply points, and a high velocity extraction system removes odorous fumes at bench level.

The new extensions will add considerably to the efficiency of the Research Department with a consequent all-round benefit to the Wakefield Castrol group of companies and, ultimately, to the users of their products throughout the world.

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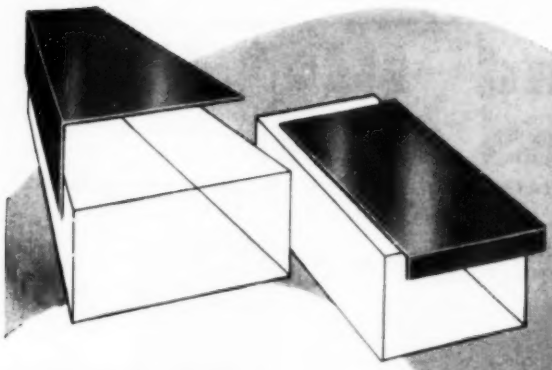
GRIFFIN & GEORGE (SALES), LTD., the laboratory furnishers, advise that their offices and warehouse at Cheetham Hill Road, Manchester, 4, are now connected to the Telex system on Telex 66–450.



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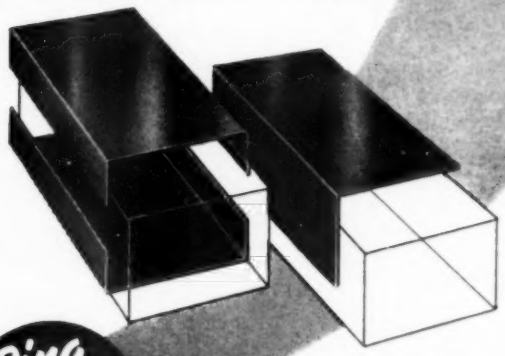

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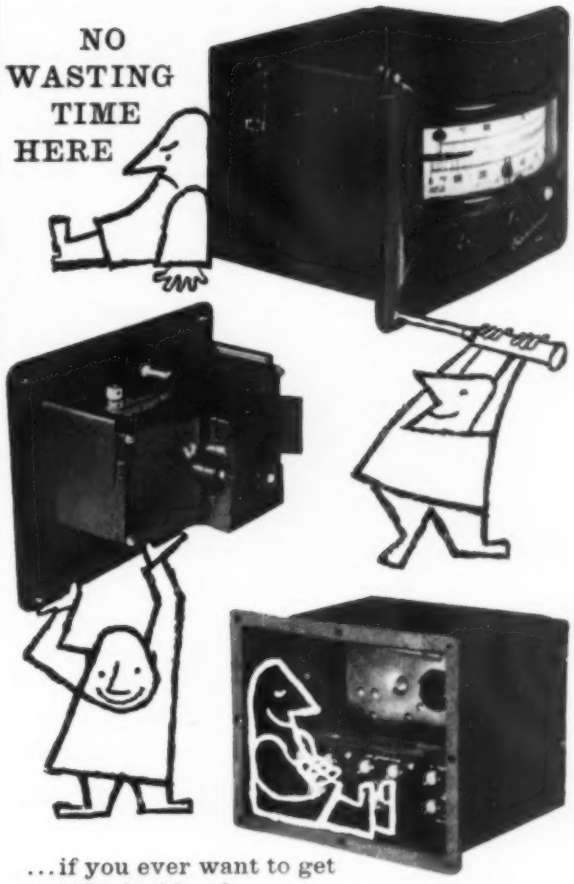

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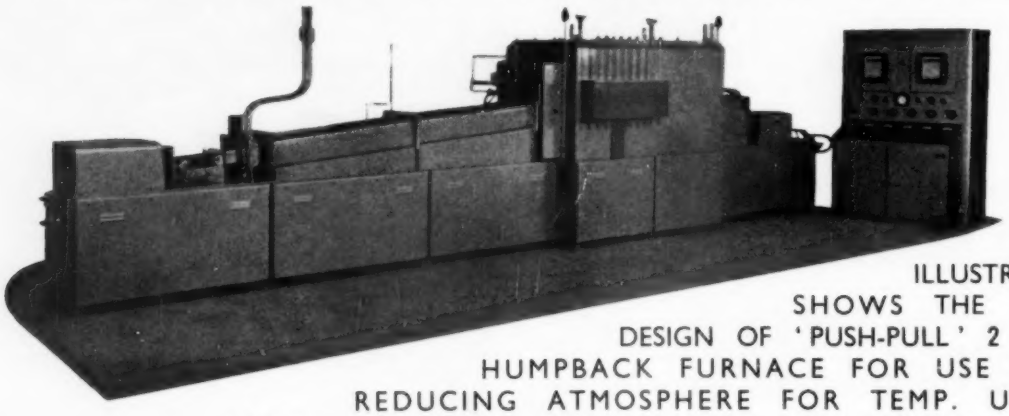

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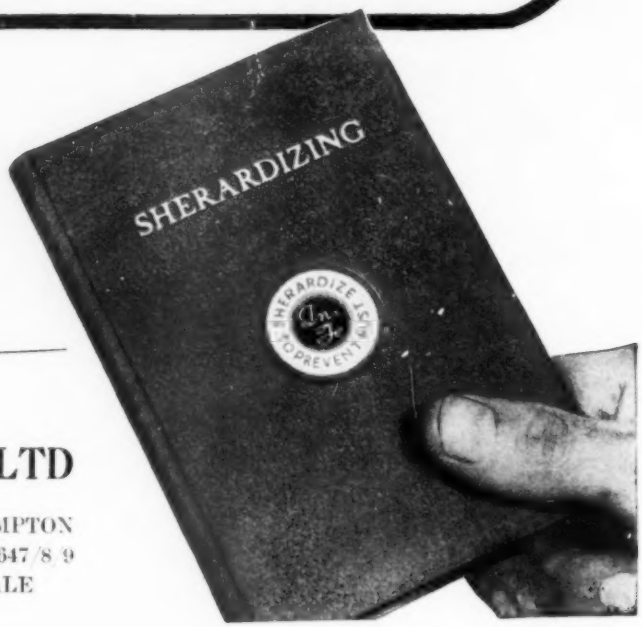

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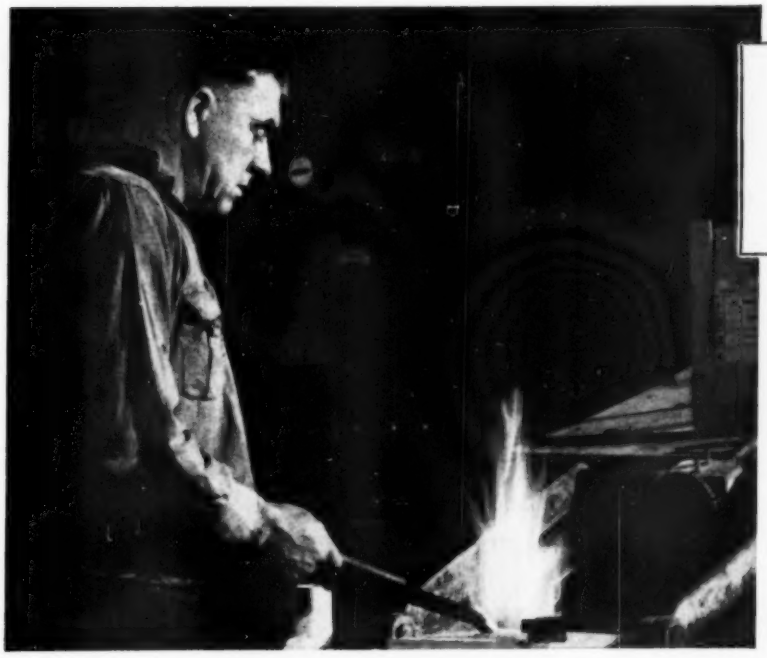

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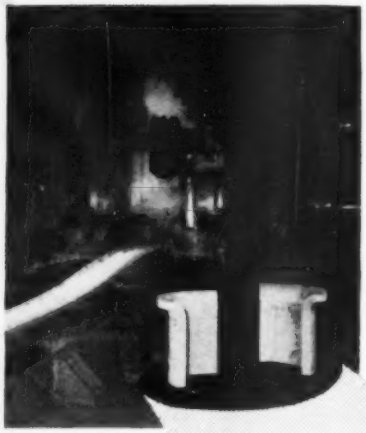

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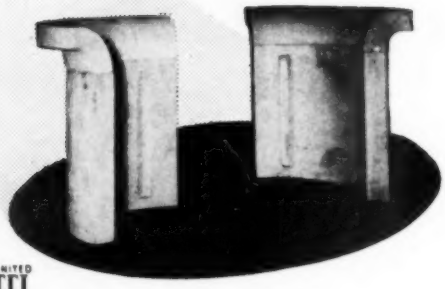

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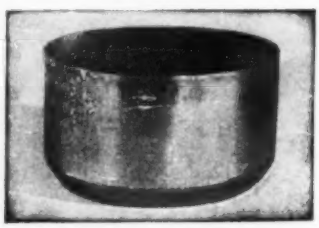

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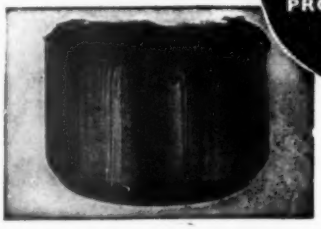

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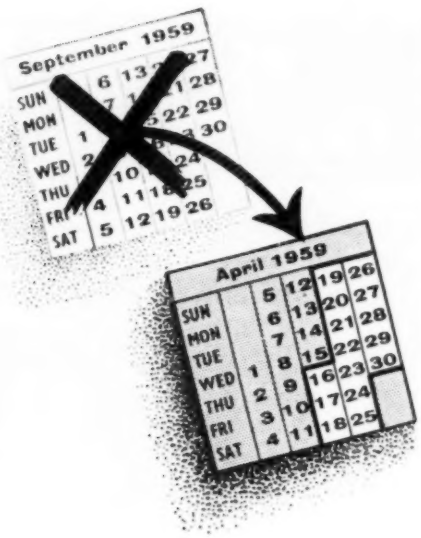

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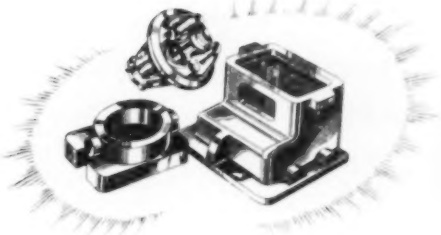

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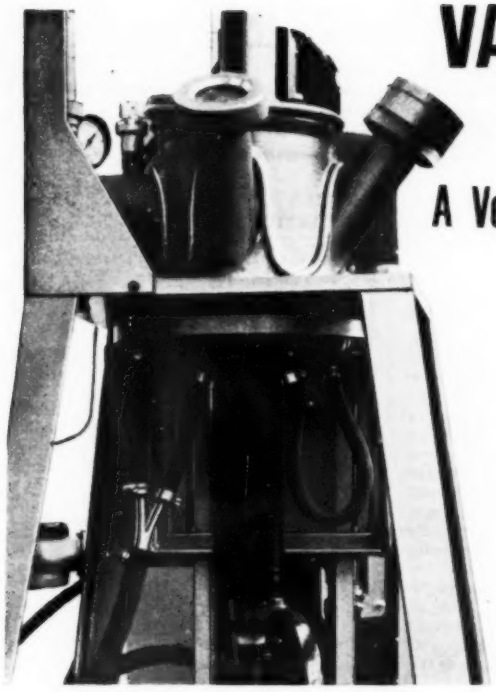

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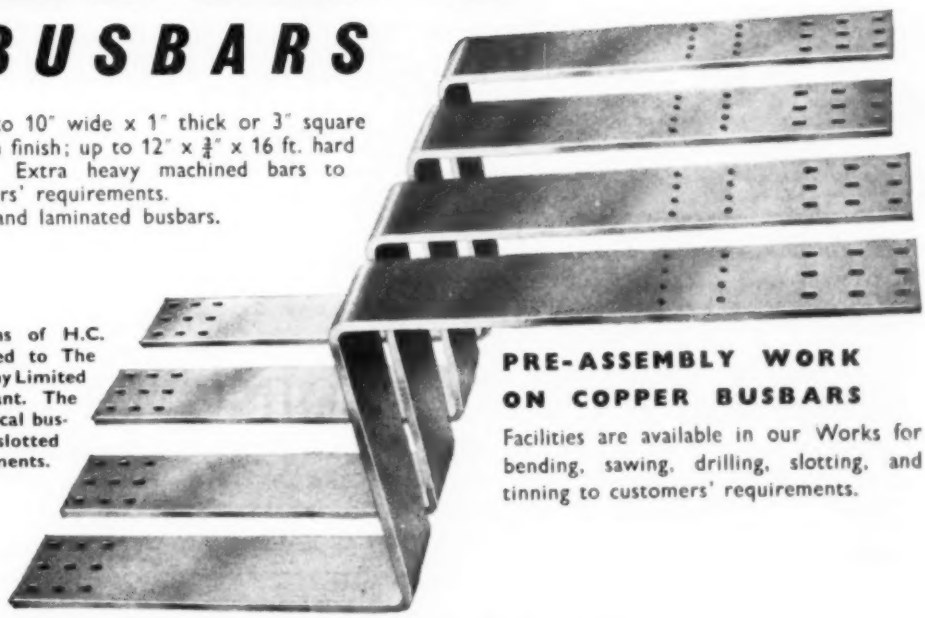

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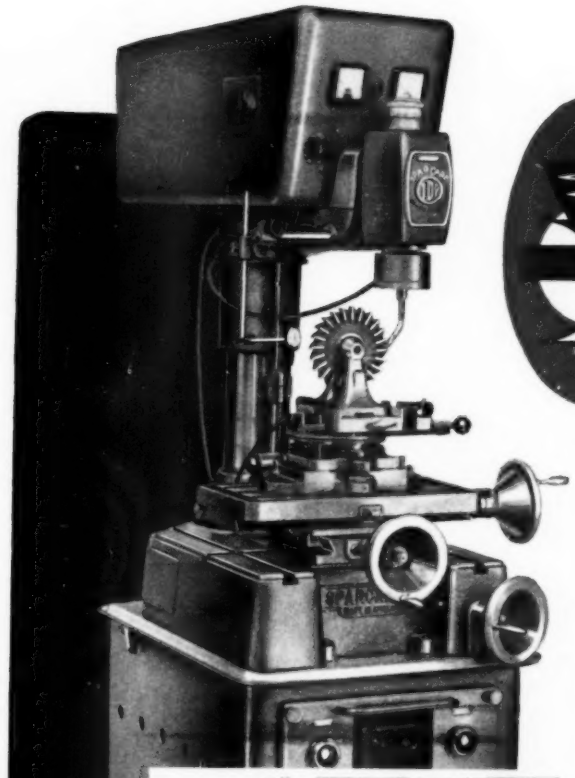

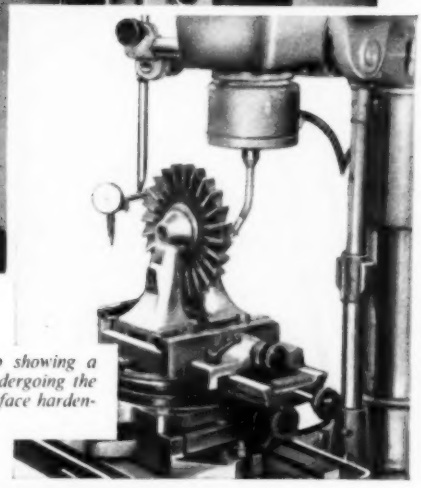

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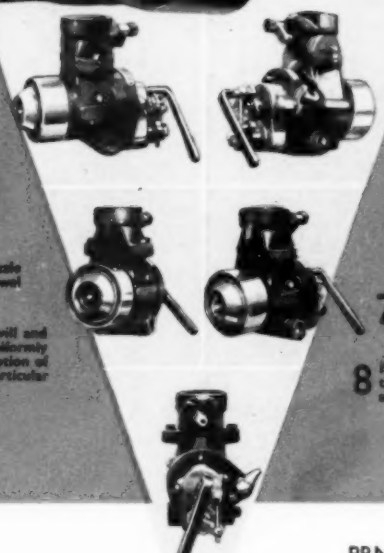

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